STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

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CALCULATION TITLE (Indicative of the Objective): Dose Calculations to Offsite Personnel from Intermodal Transfer Point	QA CATEGORY (✓) ☑ I – NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ____ OTHER

CALCULATION IDENTIFICATION NUMBER				
J. O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.01	Rad. Protection	UR-4	N.A.	N.A.

* APPROVALS – SIGNATURE & DATE			REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION *REQUIRED (✓)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE (S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
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SUBJECT/TITLE Dose Calculations to Offsite Personnel from Intermodal Transfer Point		QA CATEGORY/CODE CLASS I	

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CALCULATION OBJECTIVE

The objective of this calculation is to estimate doses to members of the public from spent fuel shipping casks at the intermodal transfer point (ITP). The dose estimates include: collective annual dose to motorists driving by the ITP on Interstate Highway 80 (I-80); collective annual dose to people traveling by rail past the ITP, and collective annual dose to people working at the nearby salt plant, approximately 2,350 ft west-northwest of the nearest shipping cask staging area at the ITP; maximum dose to an individual driving on I-80 past the ITP; maximum dose to an individual that pulls off I-80 and remains with a disabled vehicle at the closest point on the off-ramp to the ITP; and maximum dose to a railroad engineer performing switching operations nearest the ITP rail siding cask staging area.

CALCULATION METHOD / ASSUMPTIONS

The TranStor and HI-STAR shipping cask SARs (References 1 and 2) identify conservative dose rates calculated at the surfaces and at 2 meters from the shipping casks, but do not project doses at various distances from the shipping casks. Therefore, simplistic conservative methods were used to estimate dose rates at distances of interest from the shipping casks, assuming casks at the ITP are loaded with design fuel analyzed by the vendors to produce the highest dose rates.

Following are key assumptions for the various scenarios evaluated in the calculation:

- Collective annual dose to people driving by the ITP on I-80: one shipping cask loaded with design fuel is continuously staged on a heavy haul vehicle on the ITP road throughout an entire year; vehicles drive past the ITP at a speed of 60 mph; information regarding the average number of vehicles per year (9,000) and passengers per vehicle (2) obtained from Utah Department of Transportation.

- Collective annual dose to rail travelers past the ITP: one shipping cask loaded with design fuel is continuously staged on a rail car on the ITP rail siding throughout an entire year; trains pass the ITP at 50 mph; AMTRAC's Office of Government Affairs was contacted regarding the number of AMTRAC passengers traveling past the ITP, and indicated that their best estimate is 167,000 people travel by rail past the ITP on an annual basis.

- Collective annual dose to workers at the nearby salt plant: one shipping cask loaded with design fuel is continuously staged at the ITP throughout an entire year; no credit for shielding by salt plant main building structure; workers at salt plant spend 2,000 hr/yr in the main building; information regarding number of workers at salt plant (maximum of 75) obtained from Cargill Salt Personnel Dept; salt plant employees drive to and from work using route of I-80 westbound off-ramp to I-80 frontage road.

- Maximum dose to an individual driving by the ITP on I-80: three shipping casks loaded with design fuel all contribute the same to dose as the shipping cask staged on a heavy haul vehicle on the ITP road (very conservative since shipping casks are expected to be staged on the rail siding which is slightly further from I-80 than the ITP road); no credit for shielding by adjacent casks; a vehicle drives by on I-80 westbound at 60 mph;

- Maximum dose to an individual rail passenger on a train that passes by the ITP: three shipping casks loaded with design fuel are staged on rail cars on the ITP rail siding, and all three casks contribute the same to dose as the one evaluated above for collective dose to rail passengers; no credit for shielding by adjacent casks; train passes by ITP traveling at 50 mph.

- Maximum dose to an individual who pulls off I-80 and remains with a disabled vehicle at the closest point on the off-ramp to the ITP: three shipping casks loaded with design fuel are staged on heavy haul vehicles on the ITP road during a 4 hour period while the individual remains in the vicinity of the disabled vehicle.

- Maximum dose to a railroad engineer performing switching operations in the immediate vicinity of the ITP rail siding cask staging area: three shipping casks loaded with design fuel are staged on rail cars on the ITP rail siding; railroad engineer spends 1 hour in the highest dose field, nearest the central cask;

REFERENCES

1. Safety Analysis Report for the TranStor Shipping Cask System, SNC-95-71SAR, Sierra Nuclear Corporation, Docket 71-9268, Revision 1, September 1996.

2. Topical Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System, (HI-STAR 100 Cask System), Holtec Report HI-951251, Docket 71-9261, Revision 4, September 1996

3. Gollnick, Daniel A., "Basic Radiation Protection Technology", 3rd Edition, Published by Pacific Radiation Corporation, July 1994.

4. Sierra Nuclear Corporation Design Calculation No. PFS01.10.02.01, "MCNP Dose Rate Vs. Distance Calculation for a Single TranStor Cask Containing 10 Year Old Fuel", Revision 0, April 10, 1997.

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CONCLUSION

Following is a summary of the results of this calculation:

- Collective annual dose to people driving by the ITP on I-80: 394 person-mrem
- Collective annual dose to rail travelers passing the ITP: 67.3 person-mrem
- Collective annual dose to workers at the nearby salt plant (includes dose from working at plant 2,000 hr/yr and drive to/from plant by ITP): 81.3 person-mrem
- Maximum dose to an individual driving by the ITP on I-80: 2.29 E-4 mrem
- Maximum dose to an individual who pulls off I-80 and remains with a disabled vehicle at the closest point on the off-ramp to the ITP: 1.75 mrem
- Maximum dose to an individual traveling by rail past the ITP: 1.21 E-3 mrem
- Maximum dose to a railroad engineer performing switching operations nearest the ITP rail siding cask staging area: 4.8 mrem

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CALCULATION

Maximum Dose Rates 2 Meters From a Shipping Cask

Figure 5.1-1 of the TranStor Shipping SAR (Reference 1) shows points around the TranStor shipping cask at which doses were computed. Tables 5.5-9 through 5.5-16 of this SAR identify computed dose rates at the various points around the shipping casks, assuming normal conditions of transport, for design fuels having the following characteristics:

PWR Spent Fuel	BWR Spent Fuel
30,000 MWd/MTU, 5-yr cooled	35,000 MWd/MTU, 5-yr cooled
35,000 MWd/MTU, 6-yr cooled	40,000 MWd/MTU, 8-yr cooled
40,000 MWd/MTU, 7-yr cooled	50,000 MWd/MTU, 11-yr cooled
45,000 MWd/MTU, 8-yr cooled	
60,000 MWd/MTU, 15-yr cooled	

For each spent fuel case analyzed, the highest dose rate at 2 meters from the planes projected from the edges of the impact limiters of the shipping cask is point 3, at the radial center of the shipping cask. The highest dose rate at point 3 is 9.13 mrem/hr, which applies to TranStor shipping cask loaded with 45,000 MWd/MTU, 8-yr cooled PWR spent fuel. This computed dose rate for design fuel complies with the requirement in 10 CFR 71.47(c) that the dose 2 meters from the vertical planes projected from the outer edges of the conveyance be less than 10 mrem/hr.

Figure 5.1.1 of the HI-STAR Shipping SAR (Reference 2) shows points around the HI-STAR shipping cask at which doses were computed. Tables 5.1.5 and 5.1.6 identify computed dose rates at the various points around the shipping casks, assuming normal conditions of transport, for design fuels having the following characteristics:

PWR Spent Fuel	BWR Spent Fuel
40,000 MWd/MTU, 10-yr cooled	40,000 MWd/MTU, 10-yr cooled

For each of the spent fuel cases analyzed, the highest dose rate at 2 meters from the surface of the shipping cask (with impact limiters in place) is point 6, at the center of the bottom impact limiter at the bottom of the shipping cask. The highest dose rate at point 6 is 8.83 mrem/hr, which applies to TranStor shipping cask loaded with 40,000 MWd/MTU, 10-yr cooled BWR spent fuel.

Based on the above, a dose rate of 9 mrem/hr at 2 meters from a shipping cask was selected to represent a conservatively high dose rate that could be associated with either vendor's shipping cask.

Nearest Distances From the ITP to I-80

Based on measurements taken from SWEC Drawing No. 0599601-EY-9-A, the closest distance from a point along the intermodal road west of the weather enclosure, where a heavy haul trailer could possibly be staged, and the north (nearest) edge of I-80 westbound is approximately 220 ft, and to the north edge of I-80 eastbound is approximately 385 ft. It is conservative to assume that a shipping cask is staged at this point for a significant time, since it is planned to normally stage shipping casks on rail cars on the rail siding. Distances from the intermodal rail siding, where rail cars carrying shipping casks can be staged, to I-80 are greater (approximately 265 ft to westbound I-80 and 430 ft to eastbound I-80). Therefore, dose estimates to motorists traveling on I-80 are conservatively calculated based on a shipping cask staged on a heavy haul trailer parked on the intermodal road west of the intermodal weather enclosure, at the closest point to I-80.

Methodology for Evaluating Dose Rate Attenuation at Distances of Interest

Dose rates at distances beyond 2 meters from shipping casks are not presented in the TranStor and HI-STAR shipping cask SARs (References 1 and 2). Therefore, simplistic conservative methods are used to estimate dose rates at distances of interest, assuming the dose rate at 2 meters from a shipping cask is 9 mrem/hr, as discussed above. The following rule of thumb is provided in Reference 3 (Chapter 5) for gamma sources:

> "As long as the distance away from the source is at least three times the longest dimension of the source, then inverse square law calculations will give the correct answer to within a percent."

This rule of thumb is applied, and the spent fuel in the shipping cask is treated as a line source out to 3 source lengths away from the cask with a $1/r$ dependence of dose rate on distance, then as a point source for distances beyond 3 source lengths, with a $1/r^2$ dependence on distance. The source length is taken to be the length of an entire fuel assembly (not just the active fuel portion) approximately 15 ft. Since this approach does not consider attenuation of the radiation by scattering in air, it is considered to be conservative not only for the gamma source, but also for neutrons, especially at long distances. Reference 4, Section 2.0, states the following in regards to dose rates at long distances (over 2,000 ft):

> "The rate of drop off is far greater than that which would be produced by a $1/r^2$ dependence, suggesting that attenuation of radiation in air becomes a significant effect over these distances."

The dose rate (DR) at 2 meters (6.56 ft) is reduced by the following attenuation factors to calculate DR at 220 ft and 385 ft from a single shipping cask:

$$\text{DR (I-80 Westbound)} = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(220\ \text{ft})^2} = 5.5\ \text{E-2 mrem/hr}$$

$$\text{DR (I-80 Eastbound)} = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(385\ \text{ft})^2} = 1.8\ \text{E-2 mrem/hr}$$

These represent maximum dose rates to the closest points along I-80 from a single shipping cask staged at the ITP.

The following equation is used for any distances beyond 45 ft., where the distance from the shipping cask to the dose reception point is variable:

$$\text{DR} = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(R)^2}$$

Reducing gives: $\text{DR} = \frac{2{,}657}{R^2}$

Dose Calculation to Motorists Traveling I-80 Westbound

For distances beyond 2,000 ft, dose rates from a shipping cask will be negligible (< 1 μR/hr). An average dose rate can be obtained for a dose receptor approaching a shipping cask along I-80 westbound from 2,000 ft away, and reaching the point of maximum exposure (220 ft from the cask) by integrating the above equation between distances of 220 ft and 2,000 ft, as follows:

Integral $\frac{2{,}657}{R^2}$ = 2,657 (Integral $1/R^2$) = - 2,657 (R^{-1}) evaluated from 2,000 to 220 ft

= -2,657 (1/2000 - 1/220) = - 2,657(- 0.00405) = + 10.75 mrem-ft/hr

This represents the area under the curve formed by the equation DR = $2{,}657/R^2$ between the distances 220 ft and 2,000 ft, where dose rate is the y-axis and distance is the x-axis. In order to determine an integrated average dose rate to a person approaching from 2,000 ft to 220 ft from the shipping cask, this area under the curve must be divided by the distance along the x-axis (2,000 - 220 = 1,780 ft).

$$\text{Integrated Average DR} = \frac{10.75\ \text{mrem-ft/hr}}{(1{,}780\ \text{ft})} = 6.04\ \text{E-3 mrem/hr}$$

It is assumed that motorists traveling along I-80 drive past the ITP at a constant speed of 60 mph (= 88 ft/sec). The time to drive the 4,000 ft considered for dose purposes (2,000 ft approaching the nearest point to the postulated shipping cask, and 2,000 ft departing this point) is:

$$\text{Exposure time} = \frac{4{,}000 \text{ ft}}{88 \text{ ft/sec}} = 45.5 \text{ sec}$$

The total dose to a person passing by the ITP at a speed of 60 miles/hr is the integrated average dose rate times the exposure time:

Dose = (6.04 E-3 mrem/hr) (1hr/3,600 sec) (45.5 sec) = 7.63 E-5 mrem

Dose Calculation to Motorists Traveling I-80 Eastbound

This calculation uses identical methodology to that used above for the dose to I-80 westbound motorists. An integrated average dose rate can be obtained for a dose receptor approaching a shipping cask along I-80 eastbound from 2,000 ft away, and reaching the point of maximum exposure (385 ft from the cask) by integrating the above equation between distances of 385 ft and 2,000 ft, as follows:

Integral $\frac{2{,}657}{R^2}$ = 2,657 (Integral $1/R^2$) = - 2,657 (R^{-1}) evaluated from 2,000 to 385 ft

= -2,657 (1/2000 - 1/385) = - 2,657(- 0.00210) = + 5.57 mrem-ft/hr

This represents the area under the curve formed by the equation DR = $2{,}657/R^2$ between the distances 385 ft and 2,000 ft, where dose rate is plotted on the y-axis and distance on the x-axis. In order to determine an integrated average dose rate to a person approaching from 2,000 ft to 385 ft from the shipping cask, this area under the curve must be divided by the distance along the x-axis (2,000 - 385 = 1,615 ft).

$$\text{Integrated Average DR} = \frac{5.57 \text{ mrem-ft/hr}}{(1{,}615 \text{ ft})} = 3.45 \text{ E-3 mrem/hr}$$

It is again assumed that motorists traveling along I-80 drive past the ITP at a constant speed of 60 mph (= 88 ft/sec). The time to drive the approximately 4,000 ft considered for dose purposes is again 45.5 sec.

The total dose to a person passing by the ITP at a speed of 60 miles/hr is the integrated average dose rate times the exposure time:

Dose = (3.45 E-3 mrem/hr) (1hr/3,600 sec) (45.5 sec) = 4.36 E-5 mrem

Collective Annual Dose Estimate to Motorists Traveling Along I-80

It is conservatively assumed that one shipping cask containing design fuel is continually staged on a heavy haul trailer on the road leading to the intermodal weather enclosure over an entire year.

In a phone call between Jeff Johns (SWEC) and Joe Reaveley of the Utah Department of Transportation, dated 4/25/97, Mr. Reaveley provided information regarding the number of vehicles that travel past the ITP (where Skull Valley Road intersects I-80). Mr. Reaveley determined from Utah Department of Transportation records that in 1996, the average daily traffic (ADT) on I-80 (both east and west bound) in this vicinity was 8,600 vehicles. For 1997, Mr. Reaveley recommended using 9,000 vehicles per day as a reasonable estimate. Mr. Reaveley also recommended using an average vehicle occupancy of 2 for this stretch of I-80.

Assuming that one-half the vehicles passing the ITP each day (9,000/2 = 4,500 vehicles/day) are traveling eastbound and the other half westbound, following is the calculation for the annual total dose estimate:

Westbound Traffic
Dose = (4,500 vehicles/day)(365 day/yr)(2 person/vehicle)(7.63 E-5 mrem/person)
= 251 person-mrem

Eastbound Traffic
Dose = (4,500 vehicles/day)(365 day/yr)(2 person/vehicle)(4.36 E-5 mrem/person)
= 143 person-mrem

Total annual dose is the sum of annual dose to westbound and eastbound motorists along I-80:

Total Annual Dose = 251 +143 = 394 person-mrem.

Maximum Dose to Motorist Passing the ITP on I-80

At any one time, it is considered that up to 3 shipping casks could be staged at the ITP. Conservatively assuming that all 3 of these contain design fuel and contribute the same dose rates as the cask discussed above, the dose rate at the nearest point on I-80 westbound would be 3 (5.5 E-2 mrem/hr) = 0.17 mrem/hr.

The integrated dose to a person in a vehicle passing by the ITP on I-80 westbound is estimated by taking 3 times the integrated dose arrived at in the above paragraphs:

Maximum dose from 3 shipping casks = 3 (7.63 E-5 mrem/hr) = 2.29 E-4 mrem.

This approach is very conservative since it assumes a motorist on I-80 is continually exposed to radiation from all 3 casks and does not account for shielding by adjacent casks. A dose receptor located at the closest point on I-80

to the intermodal could "see" radiation from each of several shipping casks lined up on the intermodal road or rail siding (which run east-west, the same as I-80). However, when a vehicle is some distance from the intermodal, the dose receptor would see radiation primarily from the nearest cask, and it would block much of the radiation from adjacent casks located behind it.

Maximum Dose to Postulated Individual with Disabled Vehicle on Westbound I-80 Off-Ramp

This section evaluates dose that could accrue to an individual that drives their vehicle onto the off-ramp of Westbound I-80, parks the vehicle and remains in its vicinity as a result of vehicle problems such as a flat tire. The nearest distance from the side of a shipping cask assumed to be staged on a heavy haul trailer on the intermodal road to the northern edge of the I-80 westbound off-ramp is approximately 135 ft. The dose rate from a single shipping cask is calculated in the same manner as previously:

$$DR\ (\text{I-80 West off-ramp}) = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(135\ \text{ft})^2} = 0.146\ \text{mrem/hr}$$

It is conservatively assumed that 3 shipping casks staged at the ITP contribute the same dose rate as the one postulated to be staged on the intermodal road (3 shipping casks would not be staged on heavy haul trailers on the intermodal road, the closest point to the off-ramp; staging is generally on the intermodal rail siding). Assuming a person spends 4 hours in the vicinity of their disabled vehicle, the dose is calculated to be:

(0.146 mrem/hr-cask) (3 casks) (4 hours) = 1.75 mrem

Dose to Persons Traveling Past the ITP by Railroad

The Union Pacific (U.P.) railroad tracks are closer to the ITP than I-80. The closest distance from the point at which a shipping cask could be staged on the intermodal rail siding to the U.P. mainline (not the existing Timpie rail siding) is approximately 50 ft (SWEC Drawing No. 0599601-EY-9-A, "Intermodal Transfer Site Plan General Arrangement"). Assuming a single shipping cask containing design fuel is staged on the intermodal rail siding staging area, the dose rate at the U.P. railroad tracks is conservatively calculated using the same methodology discussed above, as follows:

$$DR = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(50\ \text{ft})^2} = 1.06\ \text{mrem/hr}$$

The general equation for dose rate at any distance remains: $DR = \frac{2{,}657}{R^2}$

The calculation to determine integrated doses to people traveling by rail past the ITP uses identical methodology to that used above for dose to I-80 motorists. An

integrated average dose rate can be obtained for a dose receptor approaching a shipping cask along the U.P. tracks from 2,000 ft away, and reaching the point of maximum exposure (50 ft from the cask) by integrating the above equation between distances of 50 ft and 2,000 ft, as follows:

Integral $\frac{2,657}{R^2}$ = 2,657 (Integral $1/R^2$) = - 2,657 (R^{-1}) evaluated from 2,000 to 50 ft

= -2,657 (1/2000 - 1/50) = - 2,657(- 0.0195) = + 51.81 mrem-ft/hr

This represents the area under the curve formed by the equation DR = $2,657/R^2$ between the distances 50 ft and 2,000 ft, where dose rate is plotted on the y-axis and distance on the x-axis. In order to determine an integrated average dose rate to a person approaching from 2,000 ft to 50 ft from the shipping cask, this area under the curve must be divided by the distance along the x-axis (2,000 - 50 = 1,950 ft).

Integrated Average DR = $\frac{51.81 \text{ mrem-ft/hr}}{(1,950 \text{ ft})}$ = 2.66 E-2 mrem/hr

It is assumed that trains pass the ITP travel at a constant speed of 50 mph (= 73.3 ft/sec). The time to travel the approximately 4,000 ft considered for dose purposes (2,000 ft approaching the nearest point to the postulated shipping cask, and 2,000 ft departing this point) is:

Exposure time = $\frac{4,000 \text{ ft}}{73.3 \text{ ft/sec}}$ = 54.6 sec

The total dose to a person passing by the ITP at a speed of 50 miles/hr is the integrated average dose rate times the exposure time:

Dose = (2.66 E-2 mrem/hr) (1hr/3,600 sec) (54.6 sec) = 4.03 E-4 mrem

Collective Annual Dose to Persons Traveling Past the ITP by Railroad

AMTRAC passenger trains travel the U.P. route past the ITP, with the California Zephyr carrying the vast majority of passengers. In a phone call dated 6/10/97 between Jeff Johns (SWEC) and Kevin Artl of AMTRAK - (Manager, Government Affairs), Mr. Artl indicated that his office performed an evaluation of the number of AMTRAK passengers that traveled by the point of interest in 1996, and his office's best approximation is 167,000 passengers per year. This includes passengers traveling both directions along the rail route. Kevin indicated that, while this number was not intended to include personnel traveling on freight trains or by the American Orient Tourist Train, the number of people traveling by these carriers would be insignificant in comparison to the 167,000 people estimated to travel with AMTRAK each year.

Assuming 167,000 people on trains travel past the ITP over the course of a year, annual dose to people on trains would be:

Dose = (167,000 persons)(4.03 E-4 mrem/person) = 67.3 person-mrem

Maximum Dose to a Person Traveling Past the ITP on Railroad

At any one time, it is considered that up to 3 shipping casks could be staged on the intermodal rail siding at the ITP. Conservatively assuming that all 3 of these casks contain design fuel and contribute the same dose rates as the cask discussed above, the dose rate at the nearest point between the intermodal rail siding staging area and the U.P. mainline is 3 (1.06 mrem/hr) = 3.18 mrem/hr.

The integrated dose to a person in a train passing by the ITP is estimated by taking 3 times the integrated dose arrived at in the above paragraphs:

Maximum dose from 3 shipping casks = 3 (4.03 E-4 mrem) = 1.21 E-3 mrem.

For the reasons stated above for highway travelers, this approach is very conservative since it assumes a railroad train passenger is continually exposed to radiation from all 3 casks and does not account for shielding by adjacent casks which would be significant, especially when the train is some distance from the ITP, since casks lined up east-west on the ITP rail siding shield each other from a dose receptor to the east or west.

Collective Annual Dose to Persons Working in the Nearby Salt Plant Main Building

Based on measurements taken from SWEC Drawing No. 0599601-EY-9-A, the closest distance from the center of the intermodal rail siding to the main building of the Cargill Salt plant is approximately 2,350 ft to the west-northwest.

It is assumed that one shipping cask is continuously staged on the intermodal rail siding over the course of a year. Dose rates at the salt plant main building can be conservatively approximated by treating the shipping cask as a line source for 3 times the length of the radiation source (fuel assemblies 15 ft long), then as a point source for the remainder of the distance. As done previously in this calculation, dose rates from a line source are assumed to fall off proportional to 1/r (where r represents distance from the source), and dose rates from a point source are assumed to fall off proportional to $1/r^2$. It is conservative to approximate the radiation source as a line 15 ft long, since the salt plant main building would receive a dose primarily from the end of a shipping cask rather than from the long axis, and the source would be the end of a canister, approximately 6.5 ft diameter. This would act as a point source at a distance of (3) (6 ft) = 18 ft from the shipping cask, rather than the (3) (15 ft) = 45 ft assumed in this calculation.

$$DR = (9 \text{ mrem/hr}) \frac{(6.56 \text{ ft})}{(45 \text{ ft})} \frac{(45 \text{ ft})^2}{(2{,}350 \text{ ft})^2} = 4.81 \text{ E-4 mrem/hr}$$

The dose to a worker at the salt plant main building assumed to spend 2,000 hr/yr in the building, with no credit for shielding by the building structure, is calculated to be:

(Dose = 4.81 E-4 mrem/hr) (2,000 hr/yr) = 0.96 mrem/yr

This is the annual dose to an individual based on a shipping cask with design fuel continuously staged at the ITP rail siding cask staging area. Due to the conservatism in this calculation, an individual worker at the salt plant would not be expected to accrue a dose greater than 1 mrem/yr from the ITP.

In a phone call between Jeff Johns (SWEC) and Michelle Giles (works in Personnel Dept. at the Cargill Salt plant), Ms. Giles indicated that the number of workers at the plant varies between 60 to 75 persons over the course of a year. Assuming 75 people work at the plant, each working 2,000 hr/yr, the collective dose to persons at the salt plant is estimated to be:

(0.96 mrem/yr) (75 persons) = 72.0 person-mrem/yr

Collective Annual Dose to Employees of the Nearby Salt Plant from Driving Past the ITP to and from Work

The collective annual dose is also calculated to employees of the nearby salt plant that drive past the ITP on their way to and from work at the salt plant, using the same methodology for calculating doses to motorists driving past the ITP on I-80. This calculation is based on the assumption that a shipping cask containing design fuel is continuously staged on a heavy haul trailer on the intermodal road west of the weather enclosure. It is assumed that salt plant employees approach the ITP on I-80 westbound, turn off I-80 by means of the westbound off-ramp onto the frontage road, and follow the frontage road to the nearby salt plant. The nearest distance from the side of a shipping cask assumed to be staged on a heavy haul trailer on the intermodal road to the northern edge of the I-80 westbound off-ramp is approximately 135 ft. This is the closest distance that a salt plant employee would approach to a shipping cask staged on a heavy haul trailer at the ITP, and is closer than the distance from the I-80 westbound off-ramp to the rail siding staging area, where shipping casks are normally staged. The dose rate from a single shipping cask is calculated in the same manner as previously:

$$\text{DR (I-80 West off-ramp)} = (9\ \text{mrem/hr}) \; \frac{(6.56\ \text{ft})}{(45\ \text{ft})} \; \frac{(45\ \text{ft})^2}{(135\ \text{ft})^2} = 0.146\ \text{mrem/hr}$$

The general equation for dose rate at any distance remains: $DR = \frac{2.657}{R^2}$

The calculation to determine integrated doses to salt plant employees driving past the ITP uses identical methodology to that used above for dose to I-80 and rail travelers . The above equation is integrated between distances of 135 ft and 2,000 ft, as follows:

Integral $\frac{2,657}{R^2}$ = 2,657 (Integral $1/R^2$) = - 2,657 (R^{-1}) evaluated from 2,000 to 135 ft

= -2,657 (1/2000 - 1/135) = - 2,657 (- 0.00691) = + 18.35 mrem-ft/hr

This represents the area under the curve formed by the equation DR = $2,657/R^2$ between the distances 135 ft and 2,000 ft, where dose rate is plotted on the y-axis and distance on the x-axis. In order to determine an integrated average dose rate to a person approaching from 2,000 ft to 135 ft from the shipping cask, this area under the curve must be divided by the distance along the x-axis (2,000 - 135 = 1,865 ft).

Integrated Average DR = $\frac{18.35 \text{ mrem-ft/hr}}{(1,865 \text{ ft})}$ = 9.84 E-3 mrem/hr

It is assumed that employees of the nearby salt plant driving past the ITP drive at a constant speed of 30 mph (= 44 ft/sec). The time to drive the approximately 4,000 ft considered for dose purposes (2,000 ft approaching the nearest point to the postulated shipping cask, and 2,000 ft departing this point) is:

Exposure time = $\frac{4,000 \text{ ft}}{44 \text{ ft/sec}}$ = 90.9 sec

The total dose to a person passing by the ITP at a speed of 30 miles/hr is the integrated average dose rate times the exposure time:

Dose = (9.84 E-3 mrem/hr) (1hr/3,600 sec) (90.9 sec) = 2.48 E-4 mrem

Based on 75 employees at the nearby salt plant, assuming each employee drives past the ITP twice per day, working 250 days per year (50 weeks/yr X 5 days/week), results in:

Collective Annual Dose = (75) (2) (250) (2.48 E-4 mrem) = 9.30 person-mrem

<u>Total Collective Annual Dose To Employees at the Nearby Salt Plant</u>

Adding the collective annual dose to nearby salt plant employees driving to work to the collective annual dose to the same employees working in the main building results in:

Total Collective Annual Dose = 72 person-mrem + 9.30 person-mrem
= 81.3 person-mrem

<u>Maximum Dose to Railroad Engineer Performing Switching Operations Close to Intermodal Rail Siding (Shipping Cask Staging Area)</u>

A railroad engineer performing switching operations on the U.P. rail siding adjacent to the intermodal rail siding (shipping cask staging area) could be positioned as close as approximately 20 ft from the side of a shipping cask staged at the intermodal rail siding (SWEC Drawing No. 0599601-EY-9-A, "Intermodal Transfer Site Plan General Arrangement").

At this close distance, the dose rate from a single shipping cask is approximated as a line source (1/r dependence on distance), and the dose rate at 20 ft (assuming the cask contains design fuel) is calculated to be:

$$DR = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(20\ \text{ft})} = 2.95\ \text{mrem/hr}$$

It is assumed that 3 shipping casks are staged on rail cars on the intermodal rail siding staging area, and the railroad engineer is 20 ft from the side of the central cask. With rail cars approximately 50 ft long, and casks centered on the rail cars, the engineer would be approximately 54 ft from the center of each of the outer 2 shipping casks. Dose rate from the outer casks is calculated to be:

$$DR = (9\ \text{mrem/hr})\ \frac{(6.56\ \text{ft})}{(45\ \text{ft})}\ \frac{(45\ \text{ft})^2}{(54\ \text{ft})^2} = 0.91\ \text{mrem/hr}$$

The total dose rate in this worst case position is the sum of the contributions from all 3 casks:

Total DR from 3 casks = 2.95 mrem/hr + 2 (0.91 mrem/hr) = 4.77 mrem/hr

Conservatively assuming that the railroad engineer performing the switching operation is positioned in this worst case orientation for an entire hour during a switching operation, the individual would accrue 4.8 mrem.