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Addendum 1

Analysis of Radiation Doses from Operation of Postulated Commercial Spent Fuel Transportation Systems

**Analysis of a System Containing a
Monitored Retrievable Storage Facility**

April 1992

**Work Performed under Contract
DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Richland, Washington 99352**

**U.S. Department of Energy
Chicago Field Office**

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ANALYSIS OF RADIATION DOSES
FROM OPERATION OF POSTULATED COMMERCIAL
SPENT FUEL TRANSPORTATION SYSTEMS

ANALYSIS OF A SYSTEM CONTAINING A
MONITORED RETRIEVABLE STORAGE FACILITY

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April 1992

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ABSTRACT

This addendum report extends the original study of the estimated radiation doses to the public and to workers resulting from transporting spent nuclear fuel from commercial nuclear power reactor stations through the federal waste management system (FWMS), to a system that contains a monitored retrievable storage (MRS) facility. The system concepts and designs utilized herein are consistent with those used in the original study (circa 1985-1987). Because the FWMS design is still evolving, the results of these analyses may no longer apply to the designs for casks and cask handling systems that are currently being considered.

Four system scenarios are examined and compared with the reference No-MRS scenario (all spent fuel transported directly from the reactors to the western repository in standard-capacity truck and rail casks). In Scenarios 1 and 2, an MRS facility is located in the eastern United States and ships either intact fuel assemblies or consolidated fuel rods and compacted assembly hardware in canisters. In Scenarios 3 and 4, an MRS facility is located in the western United States and ships either intact fuel assemblies or consolidated fuel rods and compacted assembly hardware in canisters.

The addition of an MRS facility to the system results in additional cask unloading and loading operations (at the MRS), which increase the radiation dose received by FWMS workers by from 134 to 237 person-rem per year, depending upon the scenario.

When the MRS facility is located in an eastern region of the U.S., those reactors located in the western region of the country ship spent fuel directly to the western repository (about 350 MTU/yr). The remaining 2650 MTU/yr are shipped via the shorter transport routes between the eastern reactors and the MRS. The radiation dose received by the public from spent fuel transport is reduced by about 193 person-rem per year, relative to the reference No-MRS scenario due to the shorter routes between the eastern reactors and the eastern MRS and the exclusive use of extra-large capacity rail casks on dedicated trains between the MRS and the western repository. Similarly, the radiation

dose received by the transport workers is reduced by about 76 person-rem/yr, relative to the reference No-MRS scenario.

When the MRS facility is located in the western U.S., all 3000 MTU/yr of spent fuel is transported to the MRS facility using standard-capacity truck and rail casks. The radiation dose received by the public from spent fuel transport is increased by about 43 person-rem per year, relative to the No-MRS scenario, due to the longer transport distances. Similarly, the radiation dose received by the transport workers is increased by about 46 person-rem/yr, relative to the reference No-MRS scenario.

The radiation dose received by the MRS and repository workers is affected significantly by whether or not the spent fuel assemblies are consolidated at the MRS and by how the residual hardware from the consolidated assemblies is treated for packaging prior to shipment. With an MRS facility in the system, the facility worker doses are reduced for the consolidation scenarios relative to the intact fuel scenarios, but all of the MRS scenarios result in a larger cumulative annual dose to system workers than the reference No-MRS scenario.

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1.0 INTRODUCTION

In the initial study (DOE 1987a) of the radiation doses received from operation of a postulated commercial spent fuel transportation system, the system consisted of the population of licensed nuclear power stations, the transportation system (truck and rail casks) for moving the spent fuel, and the cask receiving facilities at a deep geologic repository. While those initial studies were being performed, an additional facility was proposed for inclusion in the federal waste management system (FWMS). This additional facility is a monitored retrievable storage (MRS) facility (Parsons 1985; Woods et al. 1988) which can store spent fuel until the repository is ready to begin accepting and emplacing operations, serve as a marshalling center for shipments to the repository, and may possibly consolidate the spent fuel assemblies into canisters prior to storage or shipment. The possible transportation links in the FWMS are illustrated in Figure 1.1. The additional radiation dose received by FWMS workers as a result of the cask handling, unloading, and loading operations introduced into the system by the addition of the MRS facility is evaluated in this current study.

Because of the possible variations in the functions of the MRS facility, and because the facility could be located either in the eastern or western portions of the United States, four distinct operational scenarios were defined and evaluated:

- an eastern MRS facility that receives, stores, and ships intact fuel assemblies to the western repository,
- an eastern MRS facility that receives, consolidates fuel assemblies, and canisters the consolidated rods and compacted non-fuel-bearing components (NFBC) prior to storage and/or shipment to the western repository,
- a western MRS facility that receives, stores, and ships intact fuel assemblies to the western repository, and
- a western MRS facility that receives, consolidates fuel assemblies, and canisters the consolidated rods and compacted NFBC prior to storage and/or shipment to the western repository.

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FIGURE 1.1. Waste Management System Configurations Analyzed in This Study

The radiation doses from normal (non-accident) system operation calculated and estimated to be received by the workers at the reactors, the MRS facility, and the repository; by the workers in the transport area; and by the public for each of these scenarios are compared with the radiation doses received by similar groups for the reference No-MRS scenario (DOE 1987a).

A summary of the results of the total system analyses for the four MRS-system scenarios and a comparison of those results with the results from the reference No-MRS scenario are presented in Section 2. The study bases and system assumptions for these analyses are presented in Section 3. Section 4 contains the analyses of the shipping operations at the MRS facility and the receiving operations at the western repository that result in radiation dose to the facility workers. Section 5 contains the analyses of the in-transit activities that result in radiation dose to transport workers and to members

of the public. The results of the analyses of the MRS system scenarios are compared with the results from the reference No-MRS system (DOE 1987a) in Section 6. Section 7 lists the references cited in the report.

This addendum report extends the original study of the estimated radiation doses to the public and to workers resulting from transporting spent nuclear fuel from commercial nuclear power reactor stations through the federal waste management system (FWMS), to a system that contains a monitored retrievable storage (MRS) facility. The system concepts and designs utilized herein are consistent with those used in the original study (circa 1985-1987). Because the FWMS design is still evolving, the results of these analyses may no longer apply to the designs for casks and cask handling systems that are currently being considered.

2.0 SUMMARY

The radiation doses received by workers in waste management system facilities, by workers in the transportation industry, and by members of the general public resulting from the transportation-related activities of the federal waste management system (FWMS) have been estimated for the situation when the system contains a monitored retrievable storage (MRS) facility. The estimated cumulative annual radiation doses to workers and to the public for the four scenarios containing an MRS facility are compared with annual radiation doses received by the same groups in the scenario without an MRS facility in the system (the reference No-MRS system) in Table 2.1 and in Figure 2.1, for a system throughput of 3000 MTU per year of spent fuel.

The dual results for facility workers in the consolidated fuel scenarios reflect the possible variation in the number of 150-ton casks containing non-fuel-bearing components (NFBC) from the consolidated assemblies that would be shipped from the MRS facility to the repository. This variation results from different assumptions about how much the NFBC is compacted and how the NFBC is packaged (in 9-in.-square canisters or in 55-gallon drums).

TABLE 2.1. Estimated Annual Radiation Doses to Facility Workers, Transportation Workers, and the General Public Resulting from Spent Fuel Transport

<u>Operational Scenario</u>	<u>Estimated Annual Radiation Dose (person-rem yr)</u>			
	<u>Facility Workers</u>	<u>Transport Workers</u>	<u>General Public</u>	<u>Totals</u>
Eastern MRS Consol. Fuel	1010 to 1039	147	263	1420 to 1449
Western MRS Consol. Fuel	1026 to 1058	269	539	1834 to 1866
Eastern MRS Intact Fuel	1087	149	264	1500
Western MRS Intact Fuel	1113	270	540	1923
No-MRS Intact Fuel	876	223	456	1555

FIGURE 2.1. Distribution of Estimated Annual Dose by Recipient Category

From Table 2.1 it can be seen that utilizing an eastern MRS facility results in the least estimated radiation dose to transport workers and to the general public of all of the scenarios. The shorter transport distances between the reactors and the eastern MRS facility where the standard-capacity truck and rail casks are used, and the use of extra-large capacity casks and dedicated trains for the longer transport distance between the MRS facility and the repository, combine to result in lower doses to the transport workers and to the general public. On the other hand, including an MRS facility in the FWMS increases the radiation dose to the facility workers from about 15% to 27%, due to the additional unloading and loading operations at the MRS facility. Consolidating the spent fuel at an MRS facility reduces the dose to the facility workers by about 5% to 8%, compared with handling the fuel intact.

The average annual radiation doses received by the various categories of workers at the MRS and repository facilities are displayed in Table 2.2, for the western MRS facility/intact spent fuel scenario. Doses to workers at the repository are also displayed for the reference No-MRS scenario and for the eastern and western MRS scenarios, all with intact spent fuel. From the table it can be seen that if all of the workers in each category can be utilized in all locations for that category, thus distributing the total radiation dose evenly to all members of that category, the average annual doses are well below the 5 rem per year limit set by 10 CFR 20, with one exception. The maintenance-craftsmen are all utilized in the same activities and cannot be moved around to distribute the dose over a larger group. At worst, the average dose to a maintenance-craftsman is estimated to be over 19 rem/yr, nearly four times greater than the NRC limit and nearly 20 times the DOE target dose for MRS facility workers. At best, the doses to maintenance-craftsmen are estimated to be nearly 4 rem per year, exceeding the DOE target dose by almost a factor of 4. Thus, it is obvious that major changes will be required in the

TABLE 2.2. Average Annual Radiation Doses to Facility Workers from Transportation-Related Activities, by Worker Category (rem/yr)^(a)

<u>Worker Category (number)</u>	<u>Workers at West. MRS^(b)</u>	<u>Workers at the Repository</u>		
		<u>No-MRS</u>	<u>E. MRS</u>	<u>W. MRS</u>
Radiation Monitor (10)	1.75	0.81	0.28	0.16
Security Guard (8)	1.11	1.00	0.35	0.17
Facility Operator (43)	1.49	1.03	0.40	0.21
Maintenance-Craftsman (24)	19.11	13.21	5.94	3.94
Quality Technician (12)	0.96	0.42	0.14	0.08
Yard Engine Driver (4)	0.80	0.61	0.21	0.11
Crane Operator (6)	0.63	0.48	0.21	0.15

(a) Intact fuel, 3000 MTU/yr system throughput.

(b) Worker dose at eastern MRS reduced by the ratio of throughputs (2650/3000).

cask handling activities at the FWMS facilities that utilize maintenance-craftsmen. The results shown for the No-MRS scenario were observed for the maintenance-craftsmen at the repository in the original Transportation ALARA study (DOE 1987a), and the additional activities associated with loading the 150-ton casks at the MRS facility exacerbates the problem.

3.0 STUDY BASES AND SYSTEM ASSUMPTIONS

With the exception of the additional activities associated with the inclusion of a monitored retrievable storage (MRS) facility into the federal waste management system (FWMS), the basic study bases and system assumptions are identical with those used in the initial study (DOE 1987a). For the convenience of the reader, those original assumptions and the additional assumptions related to the MRS facility are summarized in this section.

3.1 AT-REACTOR ASSUMPTIONS

All spent fuel is shipped as intact assemblies, in legal-weight truck casks or 100-ton rail casks, having capacities of 2 PWR/5 BWR and 14 PWR/36 BWR assemblies, respectively. Each cask is shipped as a single shipment, on a sole-use truck, or as general freight-rail (GFR).

Cask loading operations are identical with those presented in DOE (1987a), with the same radiation dose accumulated by the facility workers per cask shipment as was derived in the original study. Thus, for all scenarios, with and without an MRS facility, the dose to reactor workers resulting from shipping 3000 MTU of intact spent fuel assemblies was estimated to be about 437 person-mrem.

3.2 IN-TRANSIT ASSUMPTIONS

In the original study, there was only one in-transit scenario: single shipments from all reactors direct to the western repository (assumed to be located at Yucca Mountain, Nevada), using the casks defined above. In this addendum, there are four distinct variations of the in-transit scenario: 1) intact fuel assemblies or 2) consolidated fuel rods plus non-fuel-bearing components (NFBC) from the eastern MRS facility (assumed to be located near Oak Ridge, Tennessee); and 3) intact fuel assemblies or 4) consolidated fuel rods plus NFBC from the western MRS facility (assumed to be located at the Idaho National Engineering Laboratory).

The shipping distances and fractions of travel for representative truck shipments between reactors and the destination facilities were developed by

averaging the data given in the repository and MRS environmental assessments (DOE 1986; DOE 1987b) except for shipments from reactors in the west to the western MRS facility. The latter approximation was based on shipments from the Trojan reactor in Oregon to the Yucca Mountain repository (DOE 1986). Shipping distances and travel fractions for shipments from the eastern and western MRS facilities to the repository were taken directly from the repository environmental assessment. The representative shipping distances and travel fractions used in this analysis are presented in Table 3.1.

Other bases and assumptions for truck and GFR shipments are the same as those given in DOE (1987a). These include shipment capacities, average speeds while moving, radiation dose rates emitted from the casks, exposure distances and times for various individuals, and numbers of individuals that are exposed at stops (e.g., state inspectors, bystanders).

TABLE 3.1. Shipping Distances and Travel Fractions for Each Transport Leg in the MRS System

<u>Transport Leg</u>		<u>Transport Mode</u>	<u>Shipping Distance, km</u>	<u>Travel Fraction^(a)</u>		
<u>Origin</u>	<u>Destination</u>			<u>Rural</u>	<u>Suburban</u>	<u>Urban</u>
Eastern Reactors	Eastern MRS	Truck	1300	0.61	0.38	0.01
		Rail	1600	0.64	0.33	0.03
	Western MRS	Truck	3300	0.81	0.18	0.01
		Rail	3330	0.80	0.19	0.01
Western Reactors	Western MRS ^(b)	Truck	2140	0.82	0.18	0.00
		Rail	2350	0.89	0.095 ^(c)	0.015
	Tuff site	Truck	1550	0.83	0.16	0.01
		Rail	1700	0.89	0.09	0.02
Eastern MRS	Yucca Mtn, site	Rail	2350	0.86	0.12	0.02
Western MRS	Yucca Mtn, site	Rail	1220	0.88	0.11	0.01

(a) Given as fraction of total shipping distance through each population density region.

(b) Based on data in DOE (1986) for shipments from Trojan to the Yucca Mountain repository site.

(c) Travel fractions in DOE (1986) added to more than 1.0 because of round-off. An equal split between urban and suburban travel was assumed for this analysis.

Dedicated trains are assumed to be used to transport spent fuel and non-fuel-bearing components (NFBC) wastes from the MRS facility to the repository. A dedicated train shipment is one in which the spent fuel and radioactive wastes from the MRS facility are the only cargo. The dedicated train shipments between the MRS facility and the repository consist of railcars carrying spent fuel casks, railcar casks carrying NFBC (when fuel consolidation is assumed), railcar casks containing high-activity wastes, and railcars carrying transuranic wastes (Cashwell et al. 1986). The dedicated train shipment also includes a locomotive, intervening flatcars between each railcar cask, and a caboose. A total of 3000 MTU/yr of spent fuel and NFBC wastes are to be transported from a western MRS facility to the repository. A total of 2650 MTU/yr of spent fuel is transported from the eastern MRS facility to the repository. The cask and shipment capacities of the various truck, general freight rail, and dedicated train shipments are presented in Table 3.2.

TABLE 3.2. Capacities of Truck, General Freight Rail, and Dedicated Train Shipments

Transport Mode	Cask Capacity, assemblies		Casks per Shipment	Shipment Capacity ^(a) (MTU/cask)	
	PWR	BWR		PWR	BWR
Truck	2	5	1	0.924	0.930
General Freight Rail	14	36	1	6.47	6.70
Dedicated Train					
- Consolidated ^(b)	56	140	5 ^(c)	129.36	130.20
- Unconsolidated	28	61	5 ^(d)	64.68	56.73

(a) Based on 0.462 MTU/PWR assembly and 0.186 MTU/BWR assembly.

(b) Shipping cask holds 28 canisters of consolidated fuel. Each canister holds 2 PWR or 5 BWR assemblies.

(c) Dedicated train shipments also include 2 railcar casks containing high-activity wastes, 1 railcar cask containing low dose rate transuranic wastes, and either 2 or 3 railcar casks containing fuel assembly hardware, depending upon whether hardware is packaged in canisters or drums, respectively.

(d) Shipment also includes one railcar cask containing high-activity wastes.

For the in-transit assumptions, information on the numbers and the types of shipments and the transport distances associated with those shipments to and from the various facilities is presented in the balance of this subsection.

- System shipments associated with an eastern MRS facility:
 - 2650 MTU per year from eastern reactors to MRS facility, Truck (606 MTU PWR/188 MTU BWR), Rail (986 MTU PWR/870 MTU BWR), single cask shipments, average distance 1300 km by truck, 1600 km by rail.
 - 350 MTU per year from western reactors direct to repository, Truck (165 MTU PWR/45 MTU BWR), Rail (140 MTU PWR/0 MTU BWR). Single cask shipments, average distance 1550 km by truck, 1700 km by rail.
 - From-MRS cask capacities: 28 PWR/61 BWR intact assemblies, 56 PWR/140 BWR consolidated rods in 28 nine-inch square canisters, 28 canisters or 20 fifty-five gallon drums of NFBC.
 - Dedicated train shipments from MRS to repository, 5 fuel casks per shipment plus casks of NFBC as appropriate, average distance 2350 km by rail.
- System shipments associated with a western MRS facility:
 - 2650 MTU per year from eastern reactors to the MRS facility, Truck (606 MTU PWR/188 MTU BWR), Rail (986 MTU PWR/870 MTU BWR), single cask shipments, average distance 3300 km by truck, 3330 km by rail.
 - 350 MTU per year from western reactors to the MRS facility, Truck (165 MTU PWR/45 MTU BWR), Rail (140 MTU PWR/0 MTU BWR), single cask shipments, average distance 2140 km by truck, 2350 km by rail.
 - From-MRS rail cask capacities same as for the eastern MRS, average distance 1220 km by rail.
- Numbers of intact fuel shipments per year:
 - Reactor to eastern MRS (858 truck casks, 282 rail casks)
 - Reactor to western repository (227 truck casks, 22 rail casks)
 - Reactor to western MRS (1085 truck casks, 304 rail casks)

- Eastern MRS to repository (123 PWR/93 BWR 150-ton rail casks)
- Western MRS to repository (147 PWR/97 BWR 150-ton rail casks)
- Numbers of consolidated fuel shipments per year:
 - Eastern MRS to repository (102 150-ton rail casks of fuel, 35 150-ton rail casks of NFBC in 9-in.-square canisters [lower bound volume] or 65 150-ton rail casks of NFBC in 55-gallon drums [upper bound volume])
 - Western MRS to repository (116 150-ton rail casks of fuel, 39 150-ton rail casks of NFBC in 9-in.-square canisters [lower bound volume] or 72 150-ton rail casks of NFBC in 55-gallon drums [upper bound volume])

Other specific assumptions related to the in-transit activities are given in the appropriate places in Section 5 of this report.

3.2.1 At-MRS Assumptions

Cask receiving and unloading operations at the MRS facility are identical with the cask receiving and unloading operations that were examined for the repository in the original study (DOE 1987a) with one exception. In this analysis, the small incremental dose resulting from the operations at the Cask Maintenance Facility has been omitted for simplicity. Those doses were estimated in the original study, were found to be quite small, and are independent of which FWMS operational scenario was examined. At the MRS facility, the same staff utilized in cask receiving operations are also utilized in cask loading and shipping operations which take place in a different part of the facility.

For consolidated fuel packaging, it is assumed that the fuel rods are packaged in 9-in.-square canisters which contain rods from either 2 PWR or 5 BWR assemblies.

For NFBC from consolidation operations, it is assumed that the NFBC material is packaged in either 9-in.-square canisters (NFBC from either 8 PWR or 10.4 BWR assemblies per canister) or in 55-gallon drums (NFBC from either 7 PWR or 7 BWR assemblies per drum). These two assumptions span the range of current assumptions being made in other studies of the operation of the FWMS.

Loading operations at the MRS facility for the 150-ton rail cask are essentially the reverse of the unloading operations for the 100-ton rail cask, except for additional QC staff time devoted to overseeing the cask loading operations.

3.2.2 At-Repository Assumptions

Cask receiving and unloading operations at the repository for the legal weight truck and 100-ton rail cask shipments are identical with the cask receiving and unloading operations that were examined in the original study (DOE 1987a). Changes resulting from the additional receipt of the 150-ton cask are: 1) the total number of casks received per year is less, and 2) a somewhat longer average time is required to remove the canisters/assemblies from the larger-capacity casks.

3.2.3 Dose Rate Assumptions

The radiation dose rates in the work areas and in the immediate vicinity of the casks are the same as those developed in Section 4.1.2.4 of DOE (1987a). For the casks, that means dose rates that are essentially at the Department of Transportation (DOT) regulatory limits.

4.0 RADIATION DOSE ESTIMATES FOR FACILITY OPERATIONS

Estimates of the annual radiation doses to workers employed in the facilities of the federal waste management system (FWMS) were developed using the same detailed, step-by-step operational analysis utilized in the spreadsheets presented in Appendix C of DOE (1987a). The receiving operations at the MRS facility were identical with the operations evaluated for the repository in the earlier study, except for the possibility of two throughput rates, 2650 MTU/yr for the eastern MRS and 3000 MTU/yr for the western MRS. For the loading operations using the 150-ton rail cask at the MRS facility, the spreadsheets were modified to reflect lower doses during receiving/cask opening operations with an empty cask and higher doses during the cask closure/decontamination/shipping operations with a loaded cask, and to reflect the longer times required to fill the larger-capacity casks. The quality assurance technicians also received longer exposures to the radiation fields around the loaded cask because of the additional observations required during the closure/decontamination/and shipping operations, compared with the observations required during the receiving/cask opening operations. The detailed spreadsheets developed for these analyses are presented in Appendix A of this addendum. The radiation doses estimated to facility workers, both MRS and repository, are presented in this section.

4.1 CASK RECEIVING, LOADING, AND SHIPPING OPERATIONS AT MRS

The various activities necessary to receive, load, and ship a 150-ton rail cask at the MRS facility, and to receive and unload the same cask at the repository, are presented in Table 4.1, together with the radiation doses received by facility workers in the performance of those activities. It can be seen from the table that the activities that produce the largest doses are those associated with handling the loaded cask. Doses from handling the empty cask are relatively minor. Actual cask loading operations are carried on from within the hot cell. As a result, doses resulting from the placement of intact assemblies or canisters of consolidated spent fuel into the 150-ton cask are minimal.

TABLE 4.1. Handling Activities and Associated Worker Radiation Doses for the 150-Ton Rail Cask at the MRS and Repository Facilities

Activity	Location	Estimated Dose per Activity (person-mrem per cask)	
		MRS	Repository
		Cask Empty	Cask Loaded
1. Receive transport vehicle and loaded (unloaded) cask at the site. Monitor, inspect, unhook off-site drive unit, attach on-site drive unit.	Gatehouse	0.000	6.250
2. Move cask/carrier to parking area and wait for wash-down station. Hook up to carrier puller when ready.	Parking Area	0.542	1.400
3. Wash cask/carrier, open personnel barrier, monitor, inspect, and dry.	Washdown Area	0.400	11.900
4. Move cask/carrier to receiving and handling area.	Receiving Bay	0.008	0.092
5. Prepare cask for removal from carrier.	Receiving Bay	1.217	64.025
6. Remove cask from carrier and place on cask cart.	Receiving Bay	0.217	4.333
7. Move cask/cart to handling room, close roll-up door.	Handling Room	0.013	0.425
8. Prepare cask for unloading (loading), position work platform, install contamination barrier adapter, remove outer lid, sample gas in cask cavity, loosen inner lid bolts, install lid lifting adapter).	Handling Room	1.154	350.092
9. Open sliding shielding door to the cask/hot cell port room, retract work platform, move cask/cart into the hot cell port room.	Cell Port Room	0.050	1.700
10. Mate the cask to the hot cell port, close shield door.	Cell Port Room	0.033	1.025
11. Remove hot cell port plugs, using cell 20-ton crane.	Hot Cell	0.083	0.083
12. Remove inner lid bolts, inner lid, fuel assembly spacer.	Hot Cell	0.242	0.242
13. Unload (load) spent fuel assemblies to (from) the hot cell lag storage.	Hot Cell	2.100	2.100
14. Monitor and vacuum cask basket/cavity (for unloading).	Hot Cell	Cask Loaded NA	Cask Empty 0.650
15. Replace fuel assembly spacer, inner lid/bolts, port plugs.	Hot Cell	0.400	0.400
16. Decouple cask from hot cell port, open shielding door.	Cell Port Room	1.442	0.025
17. Move cask/cart to handling room.	Handling Room	0.425	0.000
18. Install work platform, remove contamination barrier adapter, lid lifting adapter, close, monitor, and decontaminate cask, open roll-up door, retract platform.	Handling Room	400.475	1.650

TABLE 4.1. (contd)

Activity	Location	Estimated Dose per Activity (person-mrem per cask)	
		MRS	Repository
		Cask Loaded	Cask Empty
19. Move cask/cart to receiving bay area.	Receiving Bay	0.425	0.008
20. Place cask on transport carrier.	Receiving Bay	4.083	0.175
21. Prepare cask for shipment, install tiedowns, impact limiters, and close personnel barrier.	Receiving Bay	98.225	1.608
22. Connect on-site drive unit, move cask/carrier to inspection area, disconnect on-site drive unit.	Inspection Area	0.700	0.033
23. Hook up off-site drive unit, move to gatehouse, perform final monitoring and inspection of cask.	Gatehouse Area	13.750	0.083
24. Notify appropriate organizations of the shipment's departure.	Facility Office	0.000	0.000
		525.983	448.308

The results of the analysis of the spreadsheet for worker category doses for 150-ton rail cask loading at the MRS facility are presented in Table 4.2. The doses to the various groups of workers (radiation monitors, security guards, facility operators, maintenance-craftsmen, quality assurance technicians, yard engine drivers, and crane operators) are shown for a single cask, for the many casks loaded with intact fuel assemblies and shipped during a single year from an eastern MRS, a western MRS, and from both of those locations when the spent fuel is consolidated at the MRS prior to shipment. The number of casks loaded and shipped when the fuel is consolidated is dependent upon the assumptions made about how the non-fuel-bearing components (NFBC) of the consolidated assemblies are compacted and packaged. For the NFBC canisters (9-in.-square canisters, 15 ft long), hardware from 8 PWR or 10.4 BWR assemblies is assumed to be contained in a single canister. For the NFBC drums, hardware from 7 PWR or 7 BWR assemblies is assumed to be contained in a single 55-gallon drum. The volume of a canister and of a drum is nearly the same. The combination of the higher hardware loading fraction and the better cask loading efficiency of the canister, compared with the drum, results in 30 to 33 fewer casks to be shipped per year in the case of the NFBC canister.

TABLE 4.2. Estimated Radiation Doses per Cask Loaded, and Annual Doses to MRS Facility Workers for Loading the 150-ton Cask

Staff (a) Position	Dose/Cask (mrem)	Annual Dose to MRS Workers for Loading 150-ton Cask (person-mrem/yr)					
		Intact Fuel		Consolidated Fuel and Packaged NFBC			
		Eastern MRS (2650 MTU/yr)	Western MRS (3000 MTU/yr)	Eastern MRS (2650 MTU/yr)		Western MRS (3000 MTU/yr)	
				NFBC Canisters	NFBC Drums	NFBC Canisters	NFBC Drums
RM1 (4)	8.333	1,802.6	2,032.9	1,142.4	1,394.9	1,286.4	1,561.4
RM2 (6)	30.471	6,591.5	7,430.7	4,177.3	5,100.8	4,704.1	5,709.4
SG1 (4)	0.833	180.2	203.1	114.2	139.4	128.6	156.1
SG2 (4)	0.900	194.7	219.5	123.4	150.7	138.9	168.6
OP1 (4)	0.833	180.2	203.1	114.2	139.4	128.6	156.1
OP2 (3)	0.133	28.8	32.4	18.2	22.3	20.5	24.9
OP3 (12)	49.596	10,728.6	12,094.5	6,799.1	8,302.4	7,656.6	9,292.8
OP4 (24)	1.917	414.7	467.5	262.8	320.9	295.9	359.2
MC1 (24)	397.800	86,052.1	97,007.5	54,534.4	66,591.7	61,412.4	74,535.8
QC1 (6)	23.608	5,106.9	5,757.0	3,236.4	3,952.0	3,644.6	4,423.4
QC2 (6)	3.458	748.0	843.3	474.1	578.9	533.8	647.9
YD (4)	2.492	539.1	607.7	341.6	417.2	384.7	466.9
CO (6)	3.108	672.3	757.9	426.1	520.3	479.8	582.3
Dose	523.5	113,240	127,658	71,764	87,631	80,815	98,085
Casks/yr		216.32	243.86	137.09	167.40	154.38	187.37
Relative Dose		0.887	1.000	0.562	0.686	0.633	0.768

(a) RM1, RM2 = Radiation Monitors, SG1, SG2 = Security Guards, OP1, OP2, OP3, OP4 = Facility Operators, MC1 = Maintenance-Craftsmen, QC1, QC2 = Quality Technicians, YD = Yard Engine Driver, CO = Crane Operator. The numbers in parentheses are the numbers of workers in each category.

Because the dose to workers at the MRS for cask loading and shipping is proportional to the number of casks handled, consolidating the spent fuel assemblies at the MRS facility reduces the dose to facility workers, compared with handling intact fuel assemblies, by a factor of 1.3 to 1.6, depending upon the NFBC packaging assumption. The dose received by the workers performing fuel consolidation is negligible because that activity is conducted in highly-shielded hot cells. The cumulative annual dose to workers at the MRS is larger when the facility is in a western location, due to the increased facility throughput (3000 MTU/yr vs. 2650 MTU/yr).

The radiation doses shown in Table 4.2 must be combined with the doses resulting from receiving the spent fuel from the reactors. The results from the upper bound scenario (western MRS, intact fuel) are summarized in Table 4.3. From this table it can be seen that the radiation dose due to the

TABLE 4.3. Estimated Annual Radiation Doses to Workers at the Western MRS Facility from Transportation-Related Activities (person-mrem/yr) (a,b,c)

<u>Staff(d)</u> <u>Position</u>	<u>Dose from^(e)</u> <u>Incoming</u> <u>Truck & Rail</u>	<u>Dose from</u> <u>Outgoing</u> <u>150-ton Cask</u>	<u>Total Dose</u> <u>to MRS</u> <u>Workers</u>	<u>Average</u> <u>Dose per</u> <u>Worker/yr</u>
RM1 (4)	2,416.5	2,032.9	4,449.4	1,112.4
RM2 (6)	5,597.1	7,430.7	13,027.8	2,171.3
SG1 (4)	195.1	203.1	398.2	99.6
SG2 (4)	8,253.1	219.5	8,472.6	2,118.2
OP1 (4)	195.1	203.1	398.2	99.6
OP2 (3)	8,439.4	32.4	8,471.8	2,823.9
OP3 (12)	40,814.0	12,094.5	52,908.5	4,409.0
OP4 (24)	1,692.0	467.5	2,159.5	90.0
MC1 (24)	361,530.5	97,007.5	458,538.0	19,105.8
QC1 (6)	4,104.0	5,757.0	9,861.0	1,643.5
QC2 (6)	833.9	843.3	1,677.2	279.5
YD (4)	2,572.5	607.7	3,180.2	795.1
CO (6)	<u>3,037.9</u>	<u>757.9</u>	<u>3,795.8</u>	632.6
	439,681	127,658	567,338	

(a) Intact fuel, 3000 MTU/yr system throughput.

(b) Doses at western MRS with consolidated fuel are reduced by factors of 0.917 to 0.948, depending upon NFBC packaging assumptions.

(c) Doses at eastern MRS are reduced from those at the western MRS by the ratio of the facility throughputs (2650/3000 = 0.833).

(d) RM1, RM2 = Radiation Monitors, SG1, SG2 = Security Guards, OP1, OP2, OP3, OP4 = Facility Operators, MC1 = Maintenance-Craftsmen, QC1, QC2 = Quality Technicians, YD = Yard Engine Driver, CO = Crane Operator. The numbers in parentheses are the number of workers in each category.

(e) Data from DOE (1987a).

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cask receiving and unloading operations (wherein a large number of truck casks and 100-ton rail casks are handled) comprises about 77% of the total dose to MRS workers. Less than 23% is attributable to the loading/shipping operations with the 150-ton rail cask. This percentage is reduced to about 16% to 18% when the fuel is consolidated prior to shipment to the repository.

The average radiation dose to the various groups of workers in the facility is also shown, for the western MRS, intact fuel scenario. As was anticipated from the results of the original study (DOE 1987a), the average annual dose to several of the worker groups exceeds the DOE target dose (1 rem/yr). The maintenance-craftsmen dose also exceeds the NRC's annual dose limit of 5 rem/yr for radiation workers.

4.2 CASK RECEIVING OPERATIONS AT THE REPOSITORY

With an MRS facility in the FWMS, the number of casks received annually at the repository is reduced significantly, from about 1,389 truck and rail casks (all containing intact fuel) to as few as 137 150-ton rail casks (eastern MRS containing consolidated fuel with NFBC in canisters). The estimated annual radiation doses to the various groups of workers at the facility are presented in Table 4.4 for the eastern and western MRS scenarios with intact fuel, together with the doses per LWT cask, 100-ton rail cask, and 150-ton rail cask. It can be seen that the dose to repository workers is largest for the eastern MRS scenario, due to the larger (465 vs. 244) number of casks handled when 350 MTU of fuel is received directly from the reactors. Shipping consolidated fuel and packaged NFBC reduces the estimated dose by factors of 0.791 to 0.871 for the eastern MRS, and by factors of 0.633 to 0.768 for the western MRS, depending upon how the NFBC is packaged.

TABLE 4.4. Estimated Radiation Doses per Cask Unloaded and Annual Doses to Repository Workers for Unloading Casks Containing a Total of 3000 MTU per Year of Intact Spent Fuel (person-mrem/yr)

Staff ^(a) Position	Estimated Annual Radiation Dose to Repository Workers for Unloading Casks (person-mrem/yr)						
	Dose per ^(b) LWT Cask (mrem)	Dose per ^(b) 100-t Cask (mrem)	Dose per 150-t Cask (mrem)	Eastern MRS ^(c)		Repository Total	Western MRS ^(c)
				LWT & 100-t Rail (350 MTU/yr)	150-t Rail (2650 MTU/yr)		150-t Rail (3000 MTU/yr)
RM1 (4)	1.550	2.417	2.417	404.1	522.8	926.9	589.4
RM2 (6)	3.975	4.225	3.942	993.6	852.7	1,846.3	961.3
SG1 (4)	0.133	0.167	0.083	33.8	18.0	51.8	20.2
SG2 (4)	6.033	5.617	5.617	1,409.8	1,215.1	2,705.9	1,369.8
OP1 (4)	0.133	0.167	0.083	33.8	18.0	51.8	20.2
OP2 (3)	5.892	6.733	6.733	1,482.9	1,456.5	2,939.4	1,641.9
OP3 (12)	29.642	28.466	28.467	7,343.6	6,158.0	13,501.6	6,942.0
OP4 (24)	0.850	1.517	2.350	242.7	508.4	751.1	573.1
MC1 (24)	220.300	403.000	388.000	58,720.2	83,932.2	142,652.4	94,617.7
QC1 (6)	2.900	2.850	2.850	726.4	616.5	1,342.9	695.0
QC2 (6)	0.400	0.808	1.175	127.6	254.2	381.8	286.5
YD (4)	1.883	1.742	1.767	465.3	382.2	847.5	430.9
CO (6)	1.775	3.658	3.658	482.0	791.3	1,273.3	892.0
Dose	274.7	462.2	447.1	72,546.9	96,725.8	169,272.7	109,040.1
Casks/yr				226.69 LWT	216.32	464.86	243.86
				21.64 100-t			
Relative Dose						1.552	1.000

(a) RM1, RM2 = Radiation Monitors, SG1, SG2 = Security Guards, OP1, OP2, OP3, OP4 = Facility Operators, MC1 = Maintenance-Craftsmen, QC1, QC2 = Quality Technicians, YD = Yard Engine Driver, CO = Crane Operator. The numbers in parentheses are the number of workers in each category.

(b) Data from DOE (1987a).

(c) Consolidated fuel scenarios reduce doses for the eastern MRS (intact fuel) shown above by factors of 0.791 to 0.871 for the eastern MRS and 0.633 to 0.768 for the western MRS.

5.0 ANALYSIS OF IN-TRANSIT OPERATIONS AND RADIATION DOSES

Estimates of the unit (dose per-shipment and per-MTU) in-transit radiation doses to transport workers and to the general public resulting from truck and general freight rail (GFR) shipments from reactors and for the dedicated train shipments from the MRS facility are developed in this section. Also calculated are estimates of the cumulative annual dose to these groups resulting from transporting 3000 MTU/yr of spent fuel through the federal waste management system (FWMS). These doses are estimated for each of the system operational scenarios outlined in Section 3 of this report.

Section 5.1 contains the estimated doses from truck shipments, the estimated doses from GFR shipments are given in Section 5.2, and the estimated doses from dedicated train shipments are given in Section 5.3. Two MRS facility siting options are analyzed, an eastern site near Oak Ridge, Tennessee, and a western site at the Idaho National Engineering Laboratory. Reactors located in the eastern United States are assumed to transport their spent fuel to the MRS facility where it is consolidated and shipped to the repository. Reactors located in the western United States are assumed to transport their spent fuel directly to the repository. For the western MRS scenario, all reactors are assumed to ship their fuel to the MRS facility, and all of the fuel is moved from the MRS facility to the repository in the large 150-ton rail casks.

5.1 ANALYSIS OF IN-TRANSIT TRANSPORT OPERATIONS AND DOSES (from-reactor truck shipments)

Electronic spreadsheets were developed to facilitate the calculation of from-reactor truck shipment doses. The spreadsheets utilize the relationships developed in DOE (1987a) to calculate the exposure times for and doses to the public and transport worker groups. A description of these computations is presented below.

5.1.1 In-Transit Operations

The first step in the analysis was to estimate the amount of time a truck shipment is moving and the amount of time spent at stops. The total travel

time is estimated by dividing the total distances traveled in each population zone by the average speed in each zone and then summing over all three zones. The average travel speeds used in this analysis, which were taken from Appendix E of DOE (1987a), are 80 km/hr (50 mph) in rural areas, 40 km/hr (25 mph) in suburban areas, and 24 km/hr (15 mph) in urban areas. The average stop-time per trip was calculated by multiplying the shipping distance by 0.011 hr of stop-time per km of travel (DOE 1986). These stop-time and moving-time relationships were programmed into the spreadsheet. The total moving time and stop-time is calculated automatically by the spreadsheet using these average speeds and stop-time relationships and the distances traveled in each population zone (travel distances are input parameters).

The next steps were to program into the spreadsheet the relationship developed in DOE (1987a) to calculate the routine radiation doses. This relationship is of the following general form:

$$\text{Per-Shipment Dose} = \text{Dose Rate} \times \text{Exposure Time} \times \text{No. Of Exposed Persons}$$

The parameters/algorithms used to evaluate this relationship are presented in Table 5.1 for each exposed population group for truck shipments.

5.1.2 Collective Doses from Truck Shipments

The results of the in-transit dose calculations for truck shipments are presented in this section. Routine doses are presented for truck drivers, escorts, service attendants, state inspectors, and the general public.

The spreadsheets for calculating the collective radiation doses from truck shipments are contained in Appendix C. Summaries of the results for the four truck shipments are presented in Tables 5.2 through 5.5. Table 5.2 is for shipments from eastern reactors to an eastern MRS facility, Table 5.3 is for truck shipments from eastern reactors to the western MRS facility, Table 5.4 is for truck shipments from western reactors to the repository, and Table 5.5 is for truck shipments from western reactors to a western MRS facility. These tables summarize the doses per shipment and per MTU, as well as annual doses to workers, the public, and the hypothetical maximally exposed individual.

TABLE 5.1. Parameters/Algorithms Used to Calculate Routine Radiation Doses for Truck Shipments

Population Group ^(a)	Dose Rate mrem/hr	Exposure time, hr/shipment ^(b)	No. of Exposed Individuals
Drivers			
While moving	2.0	$\sum_i \text{DIST}_i \setminus V_i$	2
At stops			
- Near cask	0.60	$0.5 (0.11 * \sum \text{DIST}_i^{(c)})$	2
- Away from cask	0.18	$0.5 (0.11 * \sum \text{DIST}_i^{(c)})$	2
Escorts ^(d)			
While moving			
- In front	0.02	$\text{DIST (urban)} \setminus V \text{ (urban)}$	2
- Behind	0.006	$\text{DIST (urban)} \setminus V \text{ (urban)}$	2
At stops	0.18	3.0	4
Service Attendant ^(e)			
Near cask	0.60	0.67/stop	1
Away from cask	0.18	2.33/stop	1
State inspectors ^(f)	3.20	1.0/inspection	2
Public - While moving ^(g)			
Passing Vehicles		$\text{DOE} = \sum_i \text{UDF (passing vehicles)}_i * \text{DIST}_i$	
Route Population		$\text{DOE} = \sum_i \text{UDF (route population)}_i * \text{DIST}_i$	
Public - At stops ^(g)		$\text{DOE} = \sum_i \text{UDF (stops)}_i * \text{DIST}_i$	

(a) These terms are defined in DOE (1987a). For the most part, they are self-explanatory.

(b) Variables are as follows:

DIST = Distance (km)

V = Velocity (km/hr)

i = Dummy variable representing population zones

UDF = Unit dose factors (person-rem/km)

(c) Each driver is assumed to spend one-half of each stop near the cask (10 m) and the other one-half away from the cask (20 m).

(d) Two escorts are assumed to precede the shipment and two escorts follow the shipment through urban areas. Escorts are also assumed to be present for one 3-hr stop.

(e) Drivers are assumed to perform these services. These doses are included for information only.

(f) Two state inspections are included for each shipment; one occurs in the state in which the shipment originates and one in the destination state.

(g) Time/distance/dose relationships were not used for these population groups. A unit-dose factor approach was used, as described in DOE (1987a).

TABLE 5.2. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Eastern Reactors to an Eastern MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
- Drivers	103.43	111.70	88.69	2586
- Escorts	2.19	2.36	1.88	118
- Attendants ^(c)	0.82	0.89	0.70	88
- Inspectors	12.80	13.82	10.98	685
Total Transport Workers	118.4	127.9	101.6	NA
Public				
- While moving				
Passing Vehicles	24.30	26.30	20.88	1.6 ^(d)
Route Population	19.91	21.55	17.11	2.4
- At stops	183.82	198.94	157.96	58.0
Total Public Dose ^(d)	228.0	246.8	196.0	NA

NA = Not Applicable

(a) Based on 0.924 MTU/shipment (PWR fuel).

(b) Based on 794 MTU/yr; PWR/BWR fuel quantities are given in Section 3.

(c) Not included in totals. Truck refueling is typically performed by the drivers. If done by the service station attendant, the dose to drivers would be reduced.

(d) Assumes person becomes stuck in traffic next to a shipment one time per year.

TABLE 5.3. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Eastern Reactors to a Western MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
- Drivers	227.34	246.04	195.06	2955
- Escorts	2.23	2.41	1.91	122
- Attendants ^(c)	2.46	2.67	2.11	88
- Inspectors	12.80	13.85	10.98	688
Total Transport Workers	242.4	262.3	208.0	NA
Public				
- While moving				
Passing Vehicles	36.90	39.94	31.71	1.6 ^(d)
Route Population	24.55	26.57	21.10	2.4
- At stops	462.42	500.45	397.36	58.0
Total Public Dose ^(d)	523.9	567.0	450.2	NA

NA = Not Applicable

(a) Based on 0.924 MTU/shipment (PWR fuel).

(b) Based on 794 MTU/yr; PWR/BWR fuel quantities are given in Section 3.

(c) Not included in totals. Truck refueling is typically performed by the drivers. If done by the service station attendant, the dose to drivers would be reduced.

(d) Assumes person becomes stuck in traffic next to a shipment one time per year.

TABLE 5.4. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Western Reactors to the Repository

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
- Drivers	106.10	114.83	24.08	2546
- Escorts	2.19	2.37	0.50	32
- Attendants ^(c)	1.64	1.78	0.37	23
- Inspectors	12.80	13.85	2.91	182
Total Transport Workers	121.1	131.1	27.5	NA
Public				
- While moving				
Passing Vehicles	16.3	17.6	3.7	1 6 ^(d)
Route Population	10.3	11.1	2.3	0.6
- At stops	219.2	237.2	49.7	15
Total Public Dose ^(d)	245.8	265.9	55.7	NA

NA = Not Applicable

(a) Based on 0.924 MTU/shipment (PWR fuel).

(b) Based on 210 MTU/yr; PWR/BWR fuel quantities are given in Section 3.

(c) Not included in totals. Truck refueling is typically performed by the drivers. If done by the service station attendant, the dose to drivers would be reduced.

(d) Assumes person becomes stuck in traffic next to a shipment one time per year.

TABLE 5.5. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Western Reactors to a Western MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
- Drivers	144.76	156.66	32.85	2750
- Escorts	2.20	2.38	0.50	32
- Attendants ^(c)	1.64	1.78	0.37	23
- Inspectors	12.80	13.85	2.91	182
Total Transport Workers	159.8	172.9	36.3	NA
Public				
- While moving				
Passing Vehicles	22.58	24.44	5.13	1 6 ^(d)
Route Population	14.99	16.22	3.41	0.6
- At stops	297.08	321.52	67.52	15
Total Public Dose ^(d)	334.7	362.2	76.1	NA

NA = Not Applicable

(a) Based on 0.924 MTU/shipment (PWR fuel)

(b) Based on 210 MTU/yr; PWR/BWR fuel quantities are given in Section 3

(c) Not included in totals. Truck refueling is typically performed by the drivers. If done by the service station attendant, the dose to drivers would be reduced.

(d) Assumes person becomes stuck in traffic next to a shipment one time per year.

5.1.3 Maximally Exposed Individuals from Truck Shipments

Estimates of the annual doses to maximally exposed individuals for the representative truck shipments are developed in this section. The approach to developing these estimates is, in general, to multiply individual per-shipment doses by the estimated number of shipments to which the maximally exposed individual is likely to be exposed. The results of these calculations are presented in Tables 5.3 through 5.6 for the representative truck shipments. In the following discussion, maximum individual exposures are the same for both MRS facility siting options because the annual shipment quantities from eastern reactors to the eastern MRS facility are the same as those from eastern reactors to the western MRS facility. Similarly, the shipment quantities from the western reactors to the western MRS facility are the same as for shipments from western reactors to the repository. Only the final destinations and, therefore, the shipping distances and travel fractions are different.

The per-shipment doses to the truck crews were calculated by adding together the collective doses at stops and while moving and then dividing the result by two persons (see Table 5.2). This approach resulted in individual truck driver doses of about 52, 114, 53, 73 rem/shipment for the four representative truck shipment routes, respectively. Based on the one-way transit times calculated within the spreadsheets using the formulas given in Table 5.1 and an estimated 32-hr waiting time at reactors (DOE 1987a), the total duration of each shipment is estimated at about 106, 210, 112, 142 hr for the four representative truck shipment routes, respectively. Assuming each driver is available for 5400 hr/yr (DOE 1987a), each two-person driving team can move approximately 50, 26, 48, and 38 shipments/yr, respectively, over the four routes. A formula for estimating the total annual shipments for truck drivers is programmed into the spreadsheet, as shown below:

$$\text{Total Annual Shipments} = \frac{(\text{Hours available per year})}{(\text{Waiting time plus travel time per round-trip shipment})}$$

The number of hours available per year is taken to be 5,400 hr (DOE 1987a). Thus, the estimated total annual individual doses are approximately 2590, 2960, 2550, and 2750 rem/yr for the representative truck shipment routes, respectively.

An attendant at a service station where refueling is performed by an attendant would receive approximately 0.83 rem/shipment (DOE 1987a). It is assumed that the maximally exposed attendants are at the last truck stop before the MRS facility or repository. It is also assumed that this truck stop is used by 1/2 of the total shipments (total annual shipments were estimated at 858 and 227 shipments/yr from eastern and western reactors, respectively), and that the truck stop operates on a 4-shift basis, 24 hours/days, 7 days per week, with the maximally exposed service attendant exposed to 107 and 28 shipments/yr, respectively. The resulting exposures to the maximally exposed service attendants are therefore about 88 rem/yr and 23 rem/yr, respectively.

Doses to individual state inspectors were estimated in DOE (1987a) at 3.2 rem/inspection. It is conservatively assumed that the maximally exposed inspectors are at the last state border before the MRS facility and repository and that this inspection station is used by all 858 shipments/yr from eastern reactors or all 227 shipments/yr from western reactors. Assuming that there are four inspectors that share the inspections equally, each inspector would be exposed to 214 shipments/yr from eastern reactors and 57 shipments/yr from western reactors. The estimated annual doses to the maximally exposed inspectors then become about 688 and 182 rem/yr, respectively.

The doses to the maximally exposed escorts were calculated under the same assumptions that were used in DOE (1987a). The dose was estimated assuming the escort is present for a single entire stop at a distance of 20 meters from the cask and precedes the cask by 50 meters in an urban area. This resulted in a per-shipment dose of 0.56 rem per escort. Assuming that each of the shipments is escorted by one of four escort teams, each escort could be exposed to 214 shipments/yr from eastern reactors and 57 shipments/yr from western reactors. The resulting estimated annual doses to the maximally exposed escorts are about 120 rem/yr and 32 rem/yr, respectively.

The maximum annual individual dose for a member of the public (non-transport worker at truck stops) was estimated using the dose rate at 20 m from the side of the cask (0.18 rem/hr) and an assumed exposure time of 3 hours/shipment. This results in an individual dose of 0.54 rem/shipment. Assuming the truck stop operates on a 4 shift, 24 hours/day, 7 day/week basis and that this truck stop services 1/2 of the shipments, this individual could be exposed to 107 shipments/yr from eastern reactors or 28 shipments/yr from western reactors. The estimated doses to the maximally exposed members of the public at truck stops are therefore about 58 rem/yr and 15 rem/yr, respectively.

The maximum annual individual dose to a member of the public that resides near a truck route was estimated using the data given in DOE (1986, p. A-19). This document indicates that a person 30 m from a passing truck shipment receives approximately 0.00283 rem/shipment. Assuming this individual is present for the passage of all 858 shipments/yr from eastern reactors and 227 shipments/yr from western reactors, the estimated annual doses to the maximally exposed members of the public are estimated to be about 2.4 rem/year and 0.6 rem/year, respectively.

5.2 ANALYSIS OF IN-TRANSIT TRANSPORT OPERATIONS AND DOSES (from-reactor rail shipments)

The analysis of in-transit routine doses for GFR shipments from reactors is presented in this section. The representative shipment origin-destination pairs evaluated in this section are the same as those evaluated in the previous section for truck shipments (i.e., eastern reactors ship to an eastern MRS facility, eastern reactors ship to a western MRS facility, western reactors ship to the repository, and western reactors ship to the western MRS facility).

5.2.1 In-Transit Operations

The shipping distances and travel fractions given in Table 3.1 were used to develop estimates of the exposure times for the various population groups exposed to the GFR shipments. As with truck operations, average moving- and stop-times for the GFR shipments were programmed into a

spreadsheet. The average travel speeds used while moving were 32 km/hr (20 mph) in all three population zones (Wooden 1986). The average stop-time per trip was calculated using the following relationship (Ostmeyer 1986):

$$\text{Stop-time/trip} = 60 + 0.033 * \text{DIST}$$

where DIST = One-way shipping distance (km), and
Stop-time is given in hours.

Similar to the dose calculations for truck shipments, electronic spreadsheets were developed to calculate routine doses from GFR shipments. The relationship between radiation doses and exposure times, dose rates, and numbers of exposed individuals that were developed in DOE (1987a) was utilized in the spreadsheets. The parameters/algorithms used to evaluate this relationship are presented in Table 5.6.

5.2.2 Collective Doses from General Freight Rail Shipments

Estimates of the collective radiation doses for the representative GFR shipments are presented in this section. The doses are received by train crew members, employees at railyards, state inspectors, escorts, and the general public residing near the rail route and railyards.

The spreadsheets for calculating the cumulative radiation doses for GFR rail shipment are contained in Appendix C. Summaries of the doses for the four representative rail shipments are presented in Tables 5.7 through 5.10. Table 5.7 contains a summary of the doses for the representative rail shipment from eastern reactors to an eastern MRS facility site. Table 5.8 contains similar information for the representative rail shipment from eastern reactors to the western MRS facility. Table 5.9 contains similar information for the representative rail shipment from western reactors to the repository, and Table 5.10 contains this information for shipments from western reactors to the western MRS facility. The tables summarize the estimated dose per-shipment and per-MTU, the total annual collective doses, and the doses to maximally-exposed individuals.

TABLE 5.6. Parameters/Algorithms Used to Calculate Routine Radiation Doses for Shipments via General Freight Rail (GFR)

<u>Population Group^(a)</u>	<u>Dose Rate mrem/hr</u>	<u>Exposure time, hr/shipment^(b)</u>	<u>No. of Exposed Individuals</u>
Train/Railroad Crews			
While moving	0.0021	DIST \ V	5
At stops			
- Crew	0.0021	60 + (0.033 * DIST)	5
- Handlers	0.76	0.2 * (No. of stops) ^(c)	10
- Yard crew	0.0013	60 + (0.033 * DIST)	100
Escorts ^(d)			
While moving	0.06	DIST \ V	2
At stops	0.06	60 + (0.033 * DIST)	2
State inspectors ^(e)	0.76	0.5/inspection	2
Public - While moving ^(f)			
Passing Vehicles		DOE = $\sum_i \text{UDF (passing vehicles)}_i * \text{DIST}_i$	
Route Population		DOE = $\sum_i \text{UDF (route population)}_i * \text{DIST}_i$	
Public - At stops	0.00055	60 + (0.033 * DIST)	300

(a) These terms are defined in DOE (1987a). For the most part, they are self-explanatory.

(b) Variables are as follows:

DIST = Distance (km)

V = Velocity (km/hr)

i = Dummy variable representing population zones

UDF = Unit dose factors (person-rem/km)

(c) No. of stops = $2 + (0.0018 * \text{DIST})$; Ostmeier (1986).

(d) Two escorts are assumed to accompany the GFR shipment at all times.

(e) Shipments are inspected by two-person inspection teams in the state in which the shipment originates and in the destination state.

(f) Time/distance/dose relationships were not used for these population groups. A unit-dose factor approach was used, as described in DOE (1987a).

5.2.3 Maximally Exposed Individuals from General Freight Rail Shipments

Estimates of the annual doses to maximally exposed individuals for the representative rail shipments are developed in this section. The approach to developing these estimates is similar to that described for truck shipments. The results of these calculations were presented in Tables 5.7 through 5.10 for the four representative rail shipments addressed. As with the maximally exposed individuals for the representative truck shipments, the number of shipments from eastern reactors and from western reactors that an individual is exposed to is the same for both MRS facility siting options.

TABLE 5.7. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Eastern Reactors to an Eastern MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	1.71	0.26	0.48	1.8
Handlers	7.41	1.15	2.09	10.7
Yard crew	14.66	2.27	4.14	1.1
Escorts	19.52	3.02	5.51	102
Inspectors	1.52	0.23	0.43	27
Total Transport Workers	44.8	6.9	12.7	NA
Public				
- While moving				
Passing Vehicles	0.34	0.05	0.10	NA
Route Population	17.36	2.68	4.98	1.4
- At stops	14.88	2.30	4.27	3.1
Total Public Dose	32.6	5.0	9.4	NA

NA = Not Applicable

(a) Based on 6.47 MTU/shipment (PWR fuel).

(b) Based on 1856 MTU/hr; PWR/BWR shipment quantities are given in Section 3.

TABLE 5.8. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Eastern Reactors to a Western MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	2.87	0.44	0.81	1.8
Handlers	12.13	1.88	3.42	10.7
Yard crew	22.06	3.41	6.23	1.1
Escorts	32.82	5.07	9.26	102
Inspectors	1.52	0.23	0.43	27
Total Transport Workers	71.4	11.0	20.2	NA
Public				
- While moving				
Passing Vehicles	0.45	0.07	0.13	NA
Route Population	20.86	3.22	5.98	1.4
- At stops	22.39	3.46	6.42	3.1
Total Public Dose	43.7	6.8	12.5	NA

NA = Not Applicable

(a) Based on 6.47 MTU/shipment (PWR fuel).

(b) Based on 1856 MTU/hr; PWR/BWR shipment quantities are given in Section 3.

TABLE 5.9. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Western Reactors to the Repository

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	1.77	0.27	0.04	0.14
Handlers	7.67	1.19	0.17	0.8
Yard crew	15.07	2.33	0.33	0.1
Escorts	20.26	3.13	0.44	7.9
Inspectors	1.52	0.23	0.03	2.1
Total Transport Workers	46.3	7.2	1.0	NA
Public				
- While moving				
Passing Vehicles	0.17	0.03	0.004	NA
Route Population	5.29	0.82	0.11	0.1
- At stops	15.30	2.36	0.33	0.2
Total Public Dose	20.8	3.2	0.4	NA

NA = Not Applicable

(a) Based on 6.47 MTU/shipment (PWR fuel).

(b) Based on 140 MTU/hr; PWR/BWR shipment quantities are given in Section 3.

TABLE 5.10. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Eastern Reactors to an Eastern MRS Facility

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	2.22	0.34	0.05	0.14
Handlers	9.47	1.46	0.20	0.8
Yard crew	17.88	2.76	0.39	0.1
Escorts	25.32	3.91	0.55	7.9
Inspectors	1.52	0.23	0.03	2.1
Total Transport Workers	56.4	8.7	1.2	NA
Public				
- While moving				
Passing Vehicles	0.23	0.04	0.005	NA
Route Population	7.74	1.20	0.17	0.1
- At stops	18.16	2.81	0.39	0.2
Total Public Dose	26.1	4.0	0.6	NA

NA = Not Applicable

(a) Based on 6.47 MTU/shipment (PWR fuel).

(b) Based on 140 MTU/hr; PWR/BWR shipment quantities are given in Section 3.

The annual dose to individual train crew members was estimated using a per-shipment dose of 0.025 rem/shipment (DOE 1987a). Assuming that the railyard nearest to the MRS facility or repository will deliver all 282 shipments/yr from eastern reactors and 22 shipments/yr from western reactors, and assuming a four-shift, 24 hours/day, 7 days/week operation, each crew member is estimated to deliver about 70 and 6 shipments/yr, respectively. The annual doses to the maximally exposed crew members are estimated to be about 1.8 rem/yr and 0.1 rem/yr, respectively.

Radiation doses to individual state inspectors were estimated in DOE (1987a) to be 0.4 rem/inspection. Assuming 70 shipment/yr from eastern reactors and 6 shipments/yr from western reactors, the annual doses to the maximally exposed inspectors are estimated to be about 27 rem/yr and 2 rem/yr, respectively.

The radiation dose to individual train handlers was estimated in DOE (1987a) to be 0.15 rem/shipment. Assuming the nearest railyards to the destination facilities handle all shipments and that the railyards are operated on a 4 shift/day basis, each train handler would be exposed to 70 shipments/yr from eastern reactors to the MRS facility or 6 shipments/yr from western reactors to the repository. Therefore, the estimated annual doses to the maximally exposed train handlers are estimated to be about 11 rem/yr and 1 rem/yr, respectively.

The maximum annual individual dose to a member of the public residing near a rail route was estimated using data given in DOE 1986 (p. A-19). This document states that a person 30 m from a rail route receives approximately 0.00504 rem per shipment. Assuming these persons are present while all 282 shipments/yr from eastern reactors pass by or all 22 shipments/yr from western reactors pass by, the annual doses to the maximally exposed member of the public residing near the rail route are about 1.4 rem/yr and 0.1 rem/yr, respectively.

The maximum annual dose to a public resident who resides near a railyard was estimated assuming an exposure distance for 300 m from the side of the cask (the dose rate at this distance is calculated to be 0.00055 rem/hr based on calculations presented in DOE 1987a) and that this individual is present

for the entire 20 hr/stop. It was also assumed that the railyard is the last stop before the final destinations so that all 282 shipments/yr destined for the MRS facility or all 22 shipments/yr destined for the repository stop at this railyard. The annual exposures to the maximally exposed members of the public residing near a railyard are estimated to be about 3.1 and 0.2 rem/yr, respectively.

The maximum annual dose to train escorts was estimated assuming the maximally exposed escort accompanies the shipments from the last railyard to the MRS facility or repository. The exposure time is thus approximately 6 hr for both destination facilities. In DOE (1987a), the per-shipment dose to these individuals was estimated to be 0.36 rem/shipment. Assuming a single escort team accompanies all 282 shipments/yr from eastern reactors and 22 shipments/yr from western reactors, the annual doses to the maximally exposed escorts are estimated to be about 102 rem/yr and 8 rem/yr, respectively.

The maximally exposed railyard workers that are not directly involved with handling the shipments were estimated assuming they are exposed to one-fourth of the shipments (i.e., 70 shipments/yr from eastern reactors and 6 shipments/yr from western reactors). The average exposure distance for these individuals is assumed to be 200 m and the exposure time is assumed to be 12 hr/shipment (DOE 1987a). Therefore, the per-shipment individual doses are estimated to be 0.0013 rem/hr times 12 hr/shipment or 0.016 rem/shipment. The annual doses to the maximally exposed railyard workers are estimated to be about 1 rem/yr and 0.1 rem/yr for shipments from eastern and western reactors, respectively.

5.3 ANALYSIS OF IN-TRANSIT TRANSPORT OPERATIONS AND DOSES (from-MRS dedicated train rail shipments)

The analysis of in-transit operational characteristics and routine doses for dedicated train shipments between the MRS facility and the repository is presented in this section. Two potential MRS facility locations, one in the eastern United States and one in the western United States, are considered.

5.3.1 In-Transit Operations

The shipping distances and travel fractions presented in Section 3 were used to develop a time-motion analysis for each potential transport leg (i.e., eastern or western MRS facility to the repository). Average speeds while moving in each population zone plus an average stop-time per shipment were also used. The average travel speeds used were 32 km/hr (20 mph) in all three population zones (Wooden 1986). This is the same travel speed that was used for GFR shipments and is believed to be reasonable for this analysis. The average stop-time per trip was calculated using a relationship between stop-time and shipping distance for dedicated trains that was developed by Ostmeier (1986), as follows:

$$ST(d) = 2 + 0.004 * DIST$$

where $ST(d)$ = stop-time, hr

$DIST$ = one-way shipping distance, km

The time-motion analysis also requires that the number of stops on a representative dedicated train shipment be estimated. Another relationship from Ostmeier (1986) was used to estimate the number of stops, as shown below:

$$N = 2 + 0.0018 * DIST$$

where N = the number of stops

$DIST$ = one-way shipping distance, km

Using these input data, the time-motion analyses for dedicated train shipments presented in Tables 5.11 through 5.14 were developed. Table 5.11 contains the detailed time-motion analysis for a representative dedicated train shipment from the eastern MRS facility site. The important parameters for the dose calculations that were derived from the time-motion analyses are summarized in Table 5.12. Tables 5.13 and 5.14 contain similar information for dedicated train shipments from a western MRS facility site to the Yucca Mountain repository.

TABLE 5.11. Time-Motion Analysis for Shipment by Dedicated Train from an Eastern MRS Facility to the Repository^(a)

<u>Activity</u>	<u>Hours/ Activity</u>	<u>Miles Traveled</u>	<u>Cumulative</u>	
			<u>Hours</u>	<u>Miles</u>
Depart Site	0:00	0	0:00	0
Travel to classification terminal	2:00	40	2:00	40
Crew and engine change/inspection	1:00	--	3:00	40
Travel to next yard	15:00	300	18:00	340
Crew change/inspection	2:00	--	20:00	540
Travel to next yard	10:00	200	30:00	540
Crew change/inspection	1:30	--	31:30	540
Travel to next yard	10:00	200	41:30	740
Crew change/inspection	2:00	--	43:30	740
Travel to next yard	10:00	200	53:30	940
Crew change/inspection	2:00	--	55:30	940
Travel	10:00	200	65:30	1140
Crew change/inspection	2:00	--	67:30	1140
Travel	15:00	300	82:30	1440
Crew change/inspection	1:00	--	83:30	1440
Travel to repository	1:30	30	85:00	1470

(a) The number of stops was calculated using the formula given in text and then rounded up to the nearest whole number.

5.3.2 Collective Doses from Dedicated Rail Shipments (From-MRS-Facility)

Estimates of the collective radiation doses for the representative dedicated train shipments are developed in this section. As with general freight rail shipments, the doses are received by train crew members, employees at railyards, state inspectors, escorts, and the general public residing near the rail route and railyards. Estimates are also developed for the maximally exposed individuals. The calculations are performed in a manner similar to those described in DOE (1987a), that is, primarily by multiplying together an estimated exposure duration, number of exposed individuals, and a

TABLE 5.12. Summary of Operational Characteristics of Postulated Dedicated Rail Shipment from the Eastern MRS Facility to the Repository

Aggregated

Total Distance	1470 miles	Number in Crew	5
Moving Time	73:30 hours	Average Speed	17.3 mph
Stop Time	<u>11:30 hours</u>	Average Speed While Moving:	20 mph
Total Time	85:00 hours		

Details

Fractions of Travel	Rural - 86%
	Suburban - 12%
	Urban - 2%

Stops

- Inspection time (includes state and railroad inspections)	11.5 hours in yards 2 hour/trip
- Time for crew change/refueling/locomotive change	9.5 hours

TABLE 5.13. Time-Motion Analysis for Shipment by Dedicated Train from a Western MRS Facility to the Repository^(a)

<u>Activity</u>	<u>Hours/ Activity</u>	<u>Miles Traveled</u>	<u>Cumulative</u>	
			<u>Hours</u>	<u>Miles</u>
Depart site	0:00	0	0:00	0
Travel to classification terminal	2:00	40	2:00	40
Inspection/crew, locomotive change	1:00	--	3:00	40
Travel to next yard	7:30	150	10:30	190
Crew change/inspection	2:00	--	12:30	190
Travel to next yard	7:30	150	19:30	340
Crew change/inspection	1:00	--	20:30	340
Travel to next yard	10:00	200	30:30	540
Crew change/inspection	2:00	--	32:30	540
Travel to next yard	10:00	200	42:30	740
Crew change/inspection	1:00	--	43:30	740
Travel to repository	1:30	20	45:00	760

(a) The number of stops was calculated using the formula given in text and then rounded up to the nearest whole number.

TABLE 5.14. Summary of Operational Characteristics of Postulated Dedicated Rail Shipment from the Western MRS Facility to the Repository

Aggregated

Total Distance	760 miles	Number in Crew	5
Moving Time	38:00 hours	Average Speed	16.9 mph
Stop Time	<u>7:00 hours</u>	Average Speed While Moving:	20 mph
Total Time	45:00 hours		

Details

Fractions of Travel	Rural - 89%
	Suburban - 9%
	Urban - 2%

Stops

- Inspection time (includes state and railroad inspections) 7 hours in yards
2 hour/trip
- Time for marshalling/classification/carrier change activities 5 hours

calculated radiation dose rate at a specified distance. Electronic spreadsheets were developed to facilitate the in-transit dose calculations for dedicated rail shipments. Adjustments were made to the spreadsheets shown in Appendix D of DOE (1987a) to account for the differences in operational characteristics, shipping distances, and travel fractions that were developed for dedicated train shipments.

The spreadsheets for calculating the cumulative radiation doses for dedicated rail shipments are contained in Appendix C. The results of all of the potential dedicated train configurations are presented in Tables 5.15 through 5.20. Table 5.15 contains the doses from the representative dedicated train shipment from an eastern MRS facility site to the repository, assuming that fuel assembly hardware (NFBC) will be packaged in canisters and shipped in the same reference casks. Table 5.16 contains similar information as Table 5.15, except the NFBC is assumed to be packaged in 55-gal. drums. Table 5.17 is for dedicated train shipments from a storage-only (no spent fuel consolidation) MRS facility. Tables 5.18 through 5.20 summarize the doses from

TABLE 5.15. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from an Eastern MRS Facility to the Repository - NFBC in Canisters

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	29.72	0.23	0.61	16.80
Handlers	10.66	0.08	0.22	2.85
Yard crew	8.98	0.07	0.18	0.28
Escorts	32.27	0.25	0.66	45.60
Inspectors	4.56	0.04	0.09	11.40
Total Transport Workers ^(c)	86.2	0.7	1.8	NA
Public				
- While moving	89.67	0.69	1.84	0.90
- At stops	4.22	0.03	0.09	0.20
Total Public Dose ^(c)	93.9	0.7	1.9	NA

NA = Not Applicable

(a) Based on 129.36 MTU of consolidated PWR spent fuel and equivalent NFBC waste per shipment.

(b) Based on 2650 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 129.36 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 130.20 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

TABLE 5.16. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from an Eastern MRS Facility to the Repository - NFBC in Drums

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	29.72	0.23	0.61	16.80
Handlers	11.84	0.09	0.24	2.85
Yard crew	9.97	0.08	0.20	0.28
Escorts	32.27	0.25	0.66	45.60
Inspectors	5.06	0.04	0.10	11.40
Total Transport Workers ^(c)	88.9	0.7	1.8	NA
Public				
- While moving	99.63	0.77	2.04	0.9
- At stops	4.22	0.03	0.09	0.2
Total Public Dose ^(c)	103.9	0.8	2.1	NA

NA = Not Applicable

(a) Based on 129.36 MTU of consolidated PWR spent fuel and equivalent NFBC waste per shipment.

(b) Based on 2650 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 129.36 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 130.20 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

TABLE 5.17. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from an Eastern MRS Facility to the Repository - No Fuel Consolidation

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	29.72	0.46	1.29	36.12
Handlers	7.10	0.11	0.31	6.27
Yard crew	5.98	0.09	0.26	0.60
Escorts	32.27	0.50	1.40	98.04
Inspectors	3.04	0.05	0.12	24.51
Total Transport Workers ^(c)	78.1	1.2	3.4	NA
Public				
- While moving	59.78	0.92	2.45	1.9
- At stops	4.22	0.07	0.18	0.4
Total Public Dose ^(c)	64.0	1.0	2.6	NA

NA = Not Applicable

(a) Based on 64.68 MTU of consolidated PWR spent fuel and equivalent NFBC waste per shipment.

(b) Based on 2650 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 64.68 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 56.73 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

TABLE 5.18. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from a Western MRS Facility to the Repository - NFBC in Canisters

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	15.75	0.12	0.36	19.32
Handlers	7.17	0.06	0.17	3.42
Yard crew	6.04	0.05	0.14	0.32
Escorts	17.10	0.13	0.40	52.44
Inspectors	4.56	0.04	0.11	13.11
Total Transport Workers ^(c)	50.6	0.4	1.2	NA
Public				
- While moving	42.17	0.33	0.98	1.0
- At stops	2.55	0.02	0.06	0.2
Total Public Dose ^(c)	44.7	0.4	1.0	NA

NA = Not Applicable

(a) Based on 129.36 MTU of consolidated PWR spent fuel and equivalent NFBC waste per shipment.

(b) Based on 3000 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 129.36 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 130.20 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

TABLE 5.19. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from a Western MRS Facility to the Repository - NFBC in Drums

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	15.75	0.12	0.36	19.32
Handlers	7.97	0.06	0.18	3.42
Yard crew	6.71	0.05	0.16	0.32
Escorts	17.10	0.13	0.40	52.44
Inspectors	5.06	0.04	0.12	13.11
Total Transport Workers ^(c)	52.6	0.4	1.2	NA
Public				
- While moving	46.85	0.36	1.08	1.0
- At stops	2.55	0.02	0.06	0.2
Total Public Dose ^(c)	49.4	0.4	1.1	NA

NA = Not Applicable

(a) Based on 129.36 MTU of consolidated PWR spent fuel and equivalent NFBC waste per shipment.

(b) Based on 3000 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 129.36 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 130.20 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

TABLE 5.20. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments from a Western MRS Facility to the Repository - No Fuel Consolidation

Exposure Category	Collective Doses			Doses to Maximally Exposed Individual (mrem/yr)
	Person-mrem/shipment	Person-mrem/MTU ^(a)	Person-rem/yr ^(b)	
Transport Workers				
Train crew	15.75	0.24	0.77	41.16
Handlers	4.78	0.07	0.23	6.84
Yard crew	4.03	0.06	0.20	0.69
Escorts	17.10	0.26	0.83	111.72
Inspectors	3.05	0.05	0.15	27.93
Total Transport Workers ^(c)	44.7	0.7	2.2	NA
Public				
- While moving	28.10	0.43	1.30	2.2
- At stops	2.55	0.04	0.12	0.5
Total Public Dose ^(c)	30.7	0.5	1.4	NA

NA = Not Applicable

(a) Based on 64.68 MTU of consolidated PWR spent fuel per shipment.

(b) Based on 3000 MTU/yr. Considers split between PWR and BWR fuel which affects the number of shipments to which an individual will be exposed. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by 64.68 MTU/shipment and adding the result to the annual BWR fuel shipment quantity divided by 56.73 MTU/shipment.

(c) Columns may not add to totals correctly because of round-off.

dedicated train shipments from a western MRS facility to the repository. Table 5.18 is for dedicated trains containing consolidated fuel and NFBC packaged in canisters; Table 5.19 assumes the NFBC is packaged in 55-gal. drums; and Table 5.20 is for dedicated train shipments from a storage-only (no spent fuel consolidation) MRS facility. Each table contains the results of the calculation of unit dose (on dose-per-shipment and dose-per-MTU bases), the annual doses, and the results of the calculations of the doses to the maximally exposed individuals.

The bases and assumptions for the exposure distances used to calculate the doses from the dedicated train shipments are as follows. The worker-occupied location closest to a spent fuel cask was estimated at 30 m or 1.5 railcar lengths. This assumption is based on a railcar length of approximately 20 m and accounts for an intervening flatcar between the locomotive and the first spent fuel railcar. Assuming that the shipping cask is placed at the mid-point of the railcar and that the crew members are at the rear of the locomotive, this results in the crew members being about 1.5 railcar lengths from the nearest cask. It is assumed that the exposure rate to the train crew from the following railcar casks are insignificant. Exposure distances for escorts are changed from 50 m to 30 m to reflect this difference in train characteristics.

Exposure distances for the yard crew and train handlers are taken to be the same as those used in DOE (1987a). The number of train handlers is assumed to be 3 for dedicated train shipments, because the dedicated trains generally travel directly through the railyard and are not subjected to classification activities (Ostmeyer 1986). Therefore, the number of train handlers would be substantially smaller for dedicated trains.

The dose factors that are used to calculate the doses to the public while the train is moving are the same for dedicated trains and GFR shipments. Information provided by Ostmeyer (1986) is used to derive this conclusion. Population doses at stops are different because of the significantly smaller times spent in railyards. Therefore, the spreadsheets reflect these much smaller exposure times for dedicated train shipments than those used for GFR shipments.

5.3.3 Maximally Exposed Individuals from Dedicated Train Shipments

Estimates of the annual doses to maximally exposed individuals for the representative dedicated train shipments are developed in this section. The approach used to develop these estimates is similar to that described for truck shipments. The results of these calculations are presented in Tables 5.15 through 5.20 for the dedicated train shipments from eastern and western MRS facilities. The individual doses in the tables were developed based on the split between the annual number of shipments of PWR and BWR fuel from the MRS facility. The annual number of shipments is calculated by dividing the annual PWR fuel shipment quantity by the PWR fuel shipment capacity and adding the result to the annual BWR fuel shipment quantity divided by the BWR shipment capacity.

The maximum individual doses for the two NFBC packaging options (i.e., canisters vs. drums) are approximately the same because the total number of shipments is identical. However, the storage-only MRS facility options result in higher maximum individual doses for the representative dedicated train shipments because the annual number of shipments is higher. The maximum individual doses for the non-consolidated fuel shipments are the ratio of the annual numbers of shipments times the maximum individual doses for the consolidated fuel options. Therefore, the maximum individual doses for the western storage-only MRS option are approximately 2.13 times the maximum individual doses for the consolidation option. The multiplication factor for the eastern storage-only MRS option is approximately 2.15. In the following discussion, only the maximum individual doses for the consolidation option are presented.

The maximum individual doses to train crew members were estimated assuming that the longest train run for an individual crew member is 12 hr (same as for GFR shipments). As discussed previously, the exposure distance for train crew members is estimated at 30 m from the top of the cask, so the dose rate is 0.07 rem/hr (DOE 1987a). Assuming that the train crew delivers all 20 dedicated train shipments/yr from the eastern MRS facility to the repository, the total annual dose is estimated to be 17 rem/yr. Assuming that the train crew delivers all 23 dedicated train shipments/yr from the western MRS

facility to the repository, the estimated total annual dose to the maximally exposed crew member about 19 rem/yr.

Annual doses to train handlers were estimated assuming an individual train handler spends approximately 5 min/railcar in close proximity to the shipment. There are 5 casks of spent fuel and 4 casks of NFBC when fuel is consolidated at the MRS and 5 casks of intact spent fuel in each dedicated train from a store-only MRS. As a result, the maximum exposure time is estimated at 45 min/train. The exposure distance is assumed to be 10 m from the side of the cask, so the dose rate is estimated at 0.76 rem/hr (DOE 1987a). Assuming that the maximally exposed individual works at the railyard nearest to the repository and the railyard operates on a 4 shift, 24 hours/day, 7 days/week basis, the maximally exposed individual would be exposed to approximately 5 shipments/yr from an eastern MRS facility and 6 shipments/yr from a western MRS facility. The estimated annual dose to the maximally exposed train handler about 2.9 and 3.4 rem/yr, respectively.

The annual dose to a railyard employee not directly involved in handling the shipment is estimated assuming this person is located 30 m (100 ft) from the side of the passing train. According to Martin and Levitch (1988), an individual in this location would receive approximately 0.014 rem from a passing dedicated train. Assuming this person is exposed to all 20 shipments/yr from an eastern MRS facility or all 23 shipments/yr from a western MRS facility, the estimated annual dose to the maximally exposed railyard worker is about 0.28 or 0.32 rem/yr, respectively.

Escorts are assumed to accompany the dedicated train at an exposure distance of 30 m. The dose rate at this distance is approximately 0.19 rem/hr (DOE 1987a). Assuming this individual accompanies all 20 or 23 dedicated train shipments/yr for the final 12 hours of the shipment, the estimated annual dose to the maximally exposed escort is about 46 or 52 rem/yr, respectively, for shipments from an eastern or western MRS facility.

Annual doses to state inspectors were calculated assuming the inspectors spend approximately 5 min/railcar (exposure duration of 45 min/train as discussed above for train handlers) at an average distance of 10 m from the side of the casks. The dose rate at this distance is estimated at 0.76 rem/hr (DOE

1987a). Assuming that an individual state inspector inspects all 20 dedicated train shipments/yr from an eastern MRS facility or all 23 shipments/yr from a western MRS facility, the estimated annual dose to the maximally exposed inspector is approximately 11 rem/yr or 13 rem/yr, respectively.

The annual dose to the maximally exposed member of the public is calculated for a person residing 30 m from a railroad that is used to transport all 20 shipments/yr from an eastern MRS facility to the repository or all 23 shipments/yr from a western MRS facility (i.e., this individual resides along the route leading from the last railyard to the repository site). The per-shipment dose is estimated using the dose factor for GFR shipments given previously (0.00504 rem/shipment) and multiplying by 9 casks to account for the dedicated train. This results in a dose factor of 0.045 rem per 9-car dedicated train. The estimated annual dose to the maximally exposed member of the public residing near a rail track is about 0.9 or 1.0 rem/yr, respectively.

The maximum individual dose to a member of the public that resides near a railyard was calculated by assuming that this person resides 300 m from the last railyard enroute to the repository. The dose rate at 300 m from the sides of the casks is 0.00055 rem/hr (DOE 1987a). Assuming this person is present for the entire 2 hr/stop and that passage of 9 railcar casks (5 casks of fuel, 4 casks of NFBC) in a single dedicated train produces 9 times the radiation dose as passage of a single railcar cask, this person is estimated to receive 0.01 rem/shipment. Assuming this person is present as all 20 dedicated train shipments/yr from an eastern MRS facility pass by or all or 23 shipments/yr from a western MRS facility pass by, the estimated annual dose to the maximally exposed member of the public residing near a railyard is about 0.20 rem/yr or 0.23 rem/yr, respectively.

5.4 ANNUAL SYSTEM RADIATION DOSES FROM IN-TRANSIT OPERATIONS

Estimates of the total annual system doses from in-transit activities are developed in this section. These doses were estimated by adding together the calculated annual doses for the appropriate transport segments that constitute the waste management system with an integral MRS facility. The

annual system doses for two system configurations are estimated (i.e., one with an eastern MRS facility and one with a western MRS facility).

Annual system doses were calculated by multiplying the annual shipment quantities (given in Section 3) by the appropriate unit doses (person-rem/MTU) calculated previously. The calculated annual system doses for both MRS facility siting assumptions, for both NFBC packaging assumptions, and for the storage-only MRS facility configuration are presented in Table 5.21, together with the annual in-transit doses for the FWMS in the No-MRS scenario (DOE 1987a). These in-transit doses are illustrated in Figure 5.1.

The results indicate that the system configuration that produces the lowest in-transit radiation dose commitment is the system with an MRS facility located in the eastern United States. Dose reductions of about 40% and 50% relative to the non-MRS system and the system with a western MRS facility, respectively, are achievable if an MRS facility is constructed in the east. These reductions arise primarily from locating the MRS facility site near the locations of most reactors, which are concentrated in the eastern United

TABLE 5.21. Estimated Total Annual System Doses for In-Transit Operations in the Waste Management System with an MRS Facility

Affected Population Group	Annual System Collective Dose, person-rem/yr				System with No MRS Facility ^(a)
	Eastern MRS Facility		Western MRS Facility		
	NFBC in Canisters or Drums	Storage-only MRS Facility	NFBC in Canisters or Drums	Storage-only MRS Facility	
Transport Workers					
Truck	129	129	244	244	201
Rail	14	14	21	21	21
Dedicated Train	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>NA</u>
Subtotal - Workers	145	146	266	267	222
Public					
Truck	251	251	525	525	444
Rail	10	10	13	13	12
Dedicated Train	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>NA</u>
Subtotal - Public	263	264	539	540	456
GRAND TOTAL	408	410	806	808	678

NA = Not applicable

(a) Source: DOE (1987a).

FIGURE 5.1. Comparison of Estimated Annual In-Transit Radiation Doses for Systems With and Without an MRS Facility

States. This results in shorter shipping distances for a large fraction of the spent fuel shipments (i.e., the shipments that originate from eastern reactors).

Comparisons of the in-transit doses between the two NFBC packaging options and the storage-only MRS facility configuration indicate there is little difference in public and worker doses from in-transit activities. This is because the total transport system radiation doses are dominated by the truck and rail shipments to the MRS facility. Since these three options only affect the characteristics of shipments from the MRS facility to the repository, the specific MRS facility configuration or NFBC packaging option has little effect on the total annual in-transit doses.

6.0 COMPARISON OF THE MRS SCENARIOS WITH THE NO-MRS SCENARIO

The annual radiation doses to workers at the reactors due to spent fuel shipping operations and to workers at the FWMS facilities (MRS and repository) are summarized for the four system scenarios containing an MRS facility and for the reference No-MRS facility scenario in Table 6.1. Also presented in the table are the cumulative annual radiation doses to workers engaged in the

TABLE 6.1. Comparison of Estimated Cumulative Annual Radiation Doses in a Waste Management System With and Without an MRS Facility (person-rem/year)

<u>System Scenario (a)</u>	<u>At-Reactor Loading</u>	<u>Reactor/ MRS</u>	<u>Reactor/ Repos.</u>	<u>MRS Facility Receive/Ship (b)</u>	<u>In-Transit MRS/Repos.</u>	<u>Repository Receive</u>	<u>System Totals (b)</u>
<u>EMRS (CSF)</u>							
Facility Worker	436.1			368.4/71.8-87.6		134.2-147.8	1010.0/1039.3
Trans. Worker	0.2	114.2	28.9	1.1/0.3-0.4	1.6	0.6-0.6	147.0
Public		204.8	56.2		1.9-2.1		263.1
							1420 - 1449
<u>WMRS (CSF)</u>							
Facility Worker	436.1			439.7/80.8-98.1		69.0-83.8	1025.6/1057.7
Trans. Worker	0.2	265.7	NA	1.3/0.4-0.5	1.2	0.2-0.2	269.1
Public		538.2	NA		1.0-1.1		539.3
							1834 - 1866
<u>EMRS (ISF)</u>							
Facility Worker	436.1			368.4/113.2		169.7	1086.8
Trans. Worker	0.2	114.2	28.9	1.1/0.5	3.5	0.6	149.0
Public		204.8	56.2		2.8		263.8
							1500
<u>WMRS (ISF)</u>							
Facility Worker	436.1			439.7/127.7		109.0	1112.5
Trans. Worker	0.2	265.7	NA	1.3/0.6	2.3	0.3	270.4
Public		538.2	NA		1.5		539.7
							1923
<u>No-MRS (ISF)</u>							
Facility Worker	436.1			NA/NA		439.7	875.8
Trans. Worker	0.2	NA	221.6		NA	1.3	222.9
Public		NA	456.4		NA		456.4
							1555

(a) EMRS means eastern MRS, WMRS means western MRS, CSF means consolidated spent fuel, and ISF means intact spent fuel.

(b) Dual dose values refer to packaging NFBC in 9-in. canisters or in 55-gallon drums.

Note: Doses resulting from Cask Maintenance Facility operations are not included in these values.

transport of spent fuel from the reactors to the FWMS facilities, and the cumulative annual dose to members of the general public as a result of the transport operations. The in-transit dose estimates are extracted from Chapter 5 of this report for the MRS scenarios and from the original study (DOE 1987a) for the No-MRS scenario. These radiation dose estimates are also illustrated in Figure 6.1 for each of the scenarios evaluated, distributed by dose-recipient category. These same estimated doses are illustrated again in Figure 6.2, distributed by the location in the system that the dose is accumulated.

It can be seen from Table 6.1 and Figure 6.1 that the eastern MRS/consolidated fuel scenario results in the least radiation dose to the transport workers and to the general public, roughly a factor of 1.7 lower than the No-MRS scenario. On the other hand, the dose to the facility workers in the No-MRS scenario is about 15% to 18% less than in the best of the MRS scenarios. There is very little difference in the doses to transport workers and

FIGURE 6.1. Distribution of Estimated Annual Dose by Recipient Category

FIGURE 6.2. Distribution of Estimated Annual Dose by System Location

the general public for a given MRS location whether or not the fuel is consolidated, and only about an 5% to 8% difference in the facility worker dose (smaller for consolidated fuel).

Several inferences can be made from the results of the analyses presented in this report:

- The addition of an eastern MRS facility to the FWMS increases the cumulative radiation dose to facility workers by 15% to 18%, relative to the No-MRS system. However, the cumulative dose to all dose recipients (facility workers, transport workers, and the general public) is about 7% less for the MRS system.
- The very large radiation doses to maintenance-craftsmen in the system will necessitate the introduction of remote/automated equipment for performing the cask receiving/shipping operations at both the MRS facility and the repository, to assure meeting the NRC dose limit and the DOE target dose.

- Public perception about the benefits of the reduction in dose to transport workers and to the general public in the consolidated fuel scenarios may influence the decision on whether or not to incorporate spent fuel consolidation into an MRS facility.

7.0 REFERENCES

Martin, J. E., and C. Levitch. 1988. "Factors Affecting Radiation Doses from Dedicated Rail Transport of Spent Reactor Fuel." Radiation Protection Management, Volume 5, No. 3. The Techrite Co., Kentwood, Michigan.

Ostmeyer, R. M. 1986. A Revised Rail-Stop Exposure Model for Incident-Free Transport of Nuclear Waste. SAND85-2149. Sandia National Laboratories, Albuquerque, New Mexico.

Ralph M. Parsons Co. (Parsons). 1985. Integral Monitored Retrievable (MRS) Storage Facility Conceptual Design Report. MRS-11, The Ralph M. Parsons Co., Pasadena, California.

U.S. Department of Energy (DOE). 1986. Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Areas, Nevada. DOE/RW-0073, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1987a. Analyses of Radiation Doses from Operation of Postulated Commercial Spent Fuel Transportation Systems. DOE/CH-TPO-01, Prepared by the Pacific Northwest Laboratory for the U.S. Department of Energy - Chicago Operations Office, Argonne, Illinois.

U.S. Department of Energy (DOE). 1987b. MRS Submission to Congress. Volume II - Environmental Assessment for a Monitored Retrievable Storage Facility. DOE/RW-0035, Rev. 1, U.S. Department of Energy, Washington D.C.

Wooden, D. G. 1986. Railroad Transportation of Spent Nuclear Fuel. SAND86-7083. Sandia National Laboratories, Albuquerque, New Mexico.

Woods, W. D., A. K. Jowdy, C. H. Keehn, R. M. Gale, and R. I. Smith. 1988. MRS Action Plan Task B Report: Analyses of Alternative Designs and Operating Approaches for a Monitored Retrievable Storage Facility. PNL-6770, Prepared by Ralph M. Parsons Company of Delaware for Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A

TIME/DISTANCE/DOSE CALCULATIONS FOR 150-TON CASK HANDLING AT MRS

APPENDIX A

TIME/DISTANCE/DOSE CALCULATIONS FOR 150-TON CASK HANDLING AT MRS

This appendix contains the detailed spreadsheet used to calculate the radiation doses received by MRS facility workers during the operations of receiving an empty cask from the repository, loading the cask with spent fuel and/or packaged NFBC, and preparing the cask for shipment to the repository.

The time steps, dose rates, and staffing levels involved in the cask handling operations are, for the most part, identical with those developed in the appendixes to DOE (1987a). Some small changes have been made, where appropriate, to reflect the longer time required to load the larger-capacity cask, the increased QC inspections needed to prepare the loaded cask for shipment, and the increased dose rates associated with decontamination of the exterior of the loaded cask.

The operations and doses shown in the spreadsheet represent those necessary for processing a single 150-ton rail cask through the MRS facility. To calculate the annual doses to the facility staff, the doses resulting from operations on a single cask must be multiplied by the number of casks handled by the staff during a year.

Twenty-four major activities have been identified for the processing of a cask through the MRS facility. Each of those activities has a number of individual steps within it to accomplish its purpose. The attached spreadsheet contains all of the activities and all of the steps within each activity, the types and number of staff involved in each step, the time duration of exposure to radiation, and the radiation dose rate during that exposure period, for each staff member. The radiation dose to each staff member during each step is computed as the product of (the time in radiation field) X (dose rate in the radiation field). There are two components of this calculation, one for the dose rate and time of exposure in the general work area and one

for the dose rate and time of exposure in the immediate vicinity of the cask. The two components are summed to provide the total dose to a worker resulting from a given step in an activity.

The types and numbers of staff required to carry out the cask handling operations at the MRS facility are given in Table A.1. These staff members perform all of the cask handling operations at the MRS facility, both for incoming and outgoing casks. These same types and numbers of staff are required for the cask handling operations at the repository.

There is one other category of workers shown in the spreadsheet, an engine driver (ED). This category is part of the transportation worker population, not of the facility worker population. Thus, the doses received by these workers during operations at the MRS facility fall into the transport worker dose totals. While the number of individuals involved in the at-facility transportation operations is not well-defined, the dose per cask is available from the spreadsheet: Engine Driver (rail) (2.500 mrem/cask). Thus, the cumulative annual dose to this worker category from the at-facility operations can be calculated, knowing the annual number of casks passing through the facilities.

TABLE A.1. Types and Numbers of Staff Required for 150-Ton Cask Handling Operations at the MRS Facility

<u>Type of Staff</u>	<u>Number of Staff per Type</u>	<u>Dose per Cask (mrem/cask)</u>
Radiation Monitor (RM1, RM2)	10	38.804
Security Guard (SG1, SG2)	8	1.734
Facility Operator (OP1, OP2, OP3, OP4)	43	52.302
Maintenance-Craftsmen (MC1)	24	397.983
Quality Technician (QC1, QC2)	12	27.066
Yard Engine Driver (YD)	4	2.499
Crane Operator (CO)	6	<u>3.109</u>
Total Dose per Cask		523.490

No.	Activity Steps Description	Area Dose Rate (mrem/hr)	Staff			Activity Time In Minutes		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
			Type	Total Number In Area	Number Doing Cask Work	In Area	Near Cask			Cask	Area	Total
1.0	Receive transport vehicle and empty cask at the MRS site. Monitor, inspect, unhook over-the-road carrier's drive unit and attach repository drive unit.											
1.1	Railcar arrives and is spotted at fixed monitoring location outside of inspection gate. Personnel leave engine and check documentation.	0	ED	2	2	5	5 ^(a)	20	0	0.000	0.000	0.000
		0	SG1	1	1	5	5	30	0	0.000	0.000	0.000
		0	OP1	1	1	5	5	30	0	0.000	0.000	0.000
		0	RM1	1	1	5	5	30	0	0.000	0.000	0.000
1.2	Engine travels to inspection Area. Monitor railcar while driver unhooks. Security search is also performed.	0	RM1	1	1	25	25 ^(a)	10	0	0.000	0.000	0.000
		0	ED	2	1	25	25 ^(a)	20	0	0.000	0.000	0.000
		0	SG2	1	1	25	25	6	0	0.000	0.000	0.000
1.3	Yard engine is hooked up.	0	YD	1	1	10	10 ^(a)	10	0	0.000	0.000	0.000
		0	RM1	1	1	10	10	30	0	0.000	0.000	0.000
		0	SG2	1	1	10	10	30	0	0.000	0.000	0.000
										0.000	0.000	0.000
										0.000	0.000	0.000
										40 min. elapsed time		
2.0	Move the transport vehicle and cask to parking area and wait for washdown station. Hook up to car puller when ready.											
2.1	Move from inspection area to parking area.	0	YD	1	1	10	10 ^(a)	20	0	0.000	0.000	0.000
2.2	Unhook yard engine for wait.	2	YD	1	1	5	5 ^(a)	10	0	0.000	0.167	0.167
2.3	Wait for service Line.	0	0	0	0	0	0	0	0	0.000	0.000	0.000
2.4	Hook up when ready.	2	YD	1	1	10	10 ^(a)	10	0	0.000	0.333	0.333
2.5	Move to washdown station.	0.1	YD	1	1	10	10 ^(a)	20	0	0.000	0.017	0.017

A.4

Activity Steps		Area Dose Rate (mrem/hr)	Staff			Activity Time In Minutes		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
No.	Description		Type	Total Number In Area	Number Doing Cask Work	In Area	Near Cask			Cask	Area	Total
2.6	Hook up to car puller.	0.1	YD	1	1	5	5 ^(a)	10	0	0.000	0.008	0.008
		0.1	M-C1	2	0	5	0			<u>0.000</u>	<u>0.017</u>	<u>0.017</u>
										0.000	0.542	0.542
3.0	Wash transport vehicle and cask, open personnel barrier, monitor, inspect and dry.											
3.1	Manual washdown.	0.1	OP2	1	1	20	20 ^(a)	6	0.1	0.033	0.033	0.067
		0.1	M-C1	2	0	20	0			0.000	0.067	0.067
3.2	Retract personnel barrier, perform security inspection and spot washdown of road dirt by wand if necessary. Complete radiation monitoring, drying.	0.1	M-C1	2	2	10	10	3	0.2	0.067	0.033	0.100
		0.1	SG2	1	1	20	20 ^(a)	6	0.1	0.033	0.033	0.067
		0.1	RM2	1	1	20	10	50	0	0.000	0.033	0.033
		0.1	OP2	1	1	20	20	6	0.1	0.033	0.033	0.067
3.3	Cask drying.	0.1	--	0	0	15	0 ^(a)		0	<u>0.000</u>	<u>0.000</u>	<u>0.000</u>
										0.167	0.233	0.400
										55 min. elapsed time		
4.0	Move transport vehicle and cask to receiving and handling area.											
4.1	Move to receiving and handling area.	0.1	CO	1	1	5	5 ^(a)	30	0	<u>0.000</u>	<u>0.008</u>	<u>0.008</u>
										0.000	0.008	0.008
										5 min. elapsed time		
5.0	Prepare cask for removal from transport vehicle.											
5.1	Obtain and replace power hand tools.	0.1	M-C1	2	2	10	10 ^(a)	20	0	0.000	0.033	0.033
5.2	Retrieve hook and grapples with crane, connect to impact limiter.	0.1	M-C1	2	2	10	10 ^(a)	20	0	0.000	0.033	0.033
		0.1	CO	1	1	10	10	30	0	0.000	0.017	0.017
5.3	Remove impact limiters, rm check, and place in setdown area (two trips required).	0.1	M-C1	2	2	45	45 ^(a)	3	0.2	0.300	0.150	0.450
		0.1	RM2	1	1	45	5	10	0.1	0.008	0.075	0.083
		0.1	CO	1	1	45	45	30	0	0.000	0.075	0.075

[illegible]

[illegible]

A.6

Activity Steps		Area Dose Rate (mrem/hr)	Type	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
				Total Number In Area	Number Doing Cask Work	In Minutes	In Area			Near Cask	Cask	Area
No.	Description											
10.1	Mate cask to hot cell entry port.	0.1	OP3	1	1	5	5 ^(a)	10	0.05	0.004	0.008	0.013
10.2	Close shadow shield.	0.1	OP3	1	1	5	5 ^(a)	10	0.05	0.004	0.008	0.013
10.3	Close shielding door.	0.1	OP3	1	1	5	5 ^(a)	20	0	<u>0.000</u> 0.008	<u>0.008</u> 0.025	<u>0.008</u> 0.033
11.0	Using 20-ton hot cell crane, remove hot cell port plugs.									15 min. elapsed time		
11.1	20-ton crane picks up special grapple.	0.1	Op4	2		5	5 ^(a)			0.000	0.017	0.017
11.2	Remove port plugs and set aside.	0.1	OP4	2		20 ^(a)				<u>0.000</u> 0.000	<u>0.067</u> 0.083	<u>0.067</u> 0.083
12.0	Remove remaining inner lid bolts. Remove inner lid and spent fuel assembly spacer.									25 min. elapsed time		
12.1	Replace grapple with tool for bolt removal.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
12.2	Remove 4 bolts.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				0.000	0.025	0.025
12.3	Replace bolt tool with lid grapple. Remove lid, inspect, and set aside.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				0.000	0.025	0.025
12.4	Replace grapple for spent fuel, remove fuel spacer.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				<u>0.000</u> 0.000	<u>0.025</u> 0.242	<u>0.025</u> 0.242
13.0	Load csf canisters into cask.									50 min. elapsed time		

A.7

A.8

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Type	Total Number In Area	Number Doing Cask Work	In Area			Near Cask	Cask	Area	Total
No.	Description											
13.1	Load csf canisters into cask after visually inspecting (15 min./canister).	0.1	OP4	2		420 ^(a)			0.000	1.400	1.400	
		0.1	QC2	1		420			0.000	0.700	0.700	
									<u>0.000</u>	<u>2.100</u>	<u>2.100</u>	
									420 min. elapsed time			
14.0	Monitor and vacuum cask cavity and fuel basket.		(ACTIVITY NOT PERFORMED)									
15.0	Replace spent fuel assembly spacer. Replace inner lid hot cell port plugs.											
15.1	Exchange inspection tool for fuel spacer/lid grapple.	0.1	OP4	2		5 ^(a)			0.000	0.017	0.017	
		0.1	QC2	1		5			0.000	0.008	0.008	
15.2	Replace fuel spacer and lid.	0.1	OP4	2		30 ^(a)			0.000	0.100	0.100	
		0.1	QC2	1		30			0.000	0.050	0.050	
15.3	Exchange fuel spacer/lid grapple for lid bolt tool.	0.1	OP4	2		5 ^(a)			0.000	0.017	0.017	
		0.1	QC2	1		5			0.000	0.008	0.008	
15.4	Install four bolts.	0.1	OP4	2		15 ^(a)			0.000	0.050	0.050	
		0.1	QC2	1		15			0.000	0.025	0.025	
15.5	Replace lid bolt tool with plug grapple.	0.1	OP4	2		5 ^(a)			0.000	0.017	0.017	
		0.1	QC2	1		5			0.000	0.008	0.008	
15.6	Replace entry port plugs.	0.1	OP4	2		20 ^(a)			0.000	0.067	0.067	
		0.1	QC2	1		20			<u>0.000</u>	<u>0.033</u>	<u>0.033</u>	
									0.000	0.400	0.400	
									80 min. elapsed time			
16.0	Unmate cask from hot cell port. Open unloading room shielding door.											
16.1	Open shielding door.	0.1	OP3	1	1	5	5 ^(a)	20	2	0.167	0.008	0.175
16.2	Raise shadow shield.	0.1	OP3	1	1	5	5 ^(a)	10	5	0.417	0.008	0.425

A.9

Activity Steps		Area Dose Rate (mrem/hr)	Staff			Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
			Type	Total Number In Area	Number Doing Cask Work	In Minutes	In Area			Near Cask	Cask	Area
No.	Description											
16.3	Release contamination barrier.	0.1	OP3	1	1	5	5 ^(a)	6	10	<u>0.833</u>	<u>0.008</u>	<u>0.842</u>
										1.417	0.025	1.442
										15 min. elapsed time		
17.0	Move cart and cask to handling room.											
17.1	Move to handling room.	0.1	OP3	1	1	5	5 ^(a)	10	5	<u>0.417</u>	<u>0.008</u>	<u>0.425</u>
										0.417	0.008	0.425
										5 min. elapsed time		
18.0	Install platform. Remove contamination barrier and lifting adapter. Install inner and outer lids. Secure all openings to the cask. Monitor and decontaminate exterior of cask. Open roll-up door. Retract platform.											
18.1	Install platform and remove contamination barrier, adapter.	0.1	OP3	1	1	15	15	10	5	1.250	0.025	1.275
		0.1	RM2	1	1	15	15	10	5	1.250	0.025	1.275
		0.1	M-C1	2	2	15	15 ^(a)	10	5	2.500	0.050	2.550
18.2	Monitor and decontaminate external of cask as required.	0.1	RM2	1	1	40	40 ^(a)	3	30	20.000	0.067	20.067
		0.1	M-C1	2	2	40	40	10	5	6.667	0.133	6.800
		0.1	OP3	1	1	40	40	3	30	20.000	0.067	20.067
18.3	Remove lifting lid adapter.	0.1	M-C1	2	2	5	5 ^(a)	3	200	33.333	0.017	33.350
		0.1	OP3	1	1	5	5	10	5	0.417	0.008	0.425
		0.1	RM2	1	1	5	5	10	5	0.417	0.008	0.425
18.4	Install inner lid bolts and verify torque.	0.1	M-C1	2	2	30	30 ^(a)	3	200	200.000	0.100	200.100
		0.1	OP3	1	1	30	30	10	5	2.500	0.050	2.550
		0.1	QC1	1	1	30	30	10	5	2.500	0.050	2.550
18.5	Secure all sample, flush, and drain ports.	0.1	OP3	1	1	10	10 ^(a)	4	100	16.667	0.017	16.683
		0.1	M-C1	2	2	10	10	10	5	1.667	0.033	1.700
		0.1	RM2	1	1	10	10	6	10	1.667	0.017	1.683

[illegible]

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Total Number In Area	Number Doing Cask Work	In Minutes	In Area			Near Cask	Cask	Area	Total
No.	Description		Type									
21.1	Install tiedowns.	0.1	M-C1	2	2	45	45 ^(a)	3	20	30.000	0.150	30.150
		0.1	CO	1	1	45	45	30	1	0.750	0.075	0.825
		0.1	RM2	1	1	45	5	3	20	1.667	0.075	1.742
		0.1	QC1	1	1	45	45	3	20	15.000	0.075	15.075
21.2	Install impact limiters.	0.1	M-C1	2	2	45	45 ^(a)	3	20	30.000	0.150	30.150
		0.1	CO	1	1	45	45	30	1	0.750	0.075	0.825
		0.1	RM2	1	1	45	5	3	20	1.667	0.075	1.742
		0.1	QC1	1	1	45	5	3	20	1.667	0.075	1.742
21.3	Close personnel barrier, monitor and install security seals.	0.1	M-C1	2	2	15	15 ^(a)	3	20	10.000	0.050	10.050
		0.1	CO	1	1	15	0	30	1	0.000	0.025	0.025
		0.1	RM2	1	1	15	10	3	20	3.333	0.025	3.358
		0.1	QC1	1	1	15	5	3	20	1.667	0.025	1.692
A.11 21.4	Disconnect from car puller, hook up yard tractor.	0.1	YD	1	1	10	10 ^(a)	10	5	<u>0.833</u>	<u>0.017</u>	<u>0.850</u>
										97.333	0.892	98.225
										115 min. elapsed time		
22.0	Move transport vehicle and cask to inspection area. Disconnect repository drive unit.											
22.1	Move transport vehicle by yard tractor to inspection area.	0.1	YD	1	1	20	20 ^(a)	20	2	0.667	0.033	0.700
										<u>0.667</u>	<u>0.033</u>	<u>0.700</u>
										20 min. elapsed time		
23.0	Hook up over-the-road carrier. Move to gatehouse. Perform final monitoring and inspection of empty cask.											
23.1	Unhook yard engine.	0	YD	1	1	5	5 ^(a)	10	5	0.417	0.000	0.417
		0	SG2	1	1	5	5	10	5	0.417	0.000	0.417
23.2	Hook up engine and move to gatehouse.	0	ED	2	2	5	5 ^(a)	10	5	0.833	0.000	0.833
		0	SG2	1	1	5	5	10	5	0.417	0.000	0.417

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Type	Total Number In Area	Number Doing Cask Work	In Area			Near Cask	Cask	Area	Total
No.	Description											
23.3	Final monitoring and inspection.	0	ED	2	2	25	25	10	2	1.667	0.000	1.667
		0	RM1	1	1	25	25 ^(a)	3	20	8.333	0.000	8.333
		0	OP1	1	1	25	25	3	2	0.833	0.000	0.833
		0	SG1	1	1	25	25	3	2	0.833	0.000	0.833
										13.750	0.000	13.750
										35 min. elapsed time		
24.0	Notify appropriate organizations of the shipment departure.											
24.1	Notify organizations of shipment release - no exposure expected.	0				5	5 ^(a)			0.000	0.000	0.000
										0.000	0.000	0.000
Total										518.967	7.017	525.983
Total elapsed time = 1385 min.										5 min. elapsed time		

(a) Indicates critical activity that controls the elapsed time of that activity.

APPENDIX B

TIME/DISTANCE/DOSE CALCULATIONS FOR 150-TON CASK HANDLING AT THE REPOSITORY

APPENDIX B

TIME/DISTANCE/DOSE CALCULATIONS FOR 150-TON CASK HANDLING AT THE REPOSITORY

This appendix contains the detailed spreadsheet used to calculate the radiation doses received by repository facility workers during the operations of receiving a loaded cask from the MRS, unloading the cask containing spent fuel and/or packaged NFBC, and preparing the empty cask for a return shipment to the MRS facility.

The time steps, dose rates, and staffing levels involved in the cask handling operations are, for the most part, identical with those developed in the appendixes to DOE (1987a). Some small changes have been made, where appropriate, to reflect the longer time required to unload the larger-capacity cask.

The operations and doses shown in the spreadsheet represent those necessary for processing a single 150-ton rail cask through the repository surface facility. To calculate the annual doses to the facility staff, the doses resulting from operations on a single cask must be multiplied by the number of casks handled by the staff during a year.

Twenty-four major activities have been identified for the processing of a cask through the repository. Each of those activities has a number of individual steps within it to accomplish its purpose. The attached spreadsheet contains all of ten activities and all of ten steps within each activity, the types and number of staff involved in each step, the time duration of exposure to radiation, and the radiation dose rate during that exposure period, for each staff member. The radiation dose to each staff member during each step is computed as the product of (the time in radiation field) x (dose rate in the radiation field). There are two components of this calculation, one for the dose rate and time of exposure in the general work area and one for the dose rate and time of exposure in the immediate vicinity of the cask. The two components are summed to provide the total dose to a worker resulting from a given step in an activity.

The types and numbers of staff required to carry out the cask handling activities and the doses associated with those activities are given in Table B.1.

There is one other category of workers shown in the spreadsheets, an engine driver (ED). This category is part of the transportation worker population, not of the facility worker population. Thus, the doses received by these workers during operations at the repository fall into the transport worker totals. While the number of individuals involved in the at-facility transportation operations is not well-defined, the dose per cask is available from the spreadsheet: Engine Driver (rail) 1.166 mrem/cask. Thus, the cumulative annual dose to this worker category can be calculated, knowing the annual number of casks passing through the facilities.

TABLE B.1. Types and Numbers of Staff Required for 150-Ton Cask Handling Operations at the Repository

<u>Type of Staff</u>	<u>Number of Staff per Type</u>	<u>Dose per Cask (mrem/cask)</u>
Radiation Monitor (RM1, RM2)	10	6.358
Security Guard (SG1, SG2)	8	5.700
Facility Operator (OP1, OP2, OP3, OP4)	43	37.634
Maintenance-Craftsmen (MC1)	24	388.000
Quality Technician (QC1, QC2)	12	4.024
Yard Engine Driver (YD)	4	1.766
Crane Operator (CO)	6	<u>3.655</u>
Total Dose per Cask		447.137

B.3

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Total Number In Area	Number Doing Cask Work	In Minutes	Near Cask			Cask	Area	Total	
No.	Description		Type									
1.0	Receive transport vehicle and loaded cask at the repository site. Monitor, inspect, unhook over-the-road carrier's drive unit and attach repository drive unit.											
1.1	Railcar arrives and is spotted at fixed monitoring location outside of inspection gate. Personnel leave engine and check documentation.	0	ED	2	2	5	5 ^(a)	20	2	0.333	0.000	0.333
		0	SG1	1	1	5	5	30	1	0.083	0.000	0.083
		0	OP1	1	1	5	5	30	1	0.083	0.000	0.083
		0	RM1	1	1	5	5	30	1	0.083	0.000	0.083
1.2	Engine travels to inspection area. Monitor railcar while driver unhooks. Security search is also performed.	0	RM1	1	1	25	25 ^(a)	6	5	2.083	0.000	2.083
		0	ED	2	1	25	25 ^(a)	20	2	0.833	0.000	0.833
		0	SG2	1	1	25	25	6	5	2.083	0.000	2.083
1.3	Yard engine is hooked up.	0	YD	1	1	10	10 ^(a)	10	2	0.333	0.000	0.333
		0	RM1	1	1	10	10	30	1	0.167	0.000	0.167
		0	SG2	1	1	10	10	30	1	0.167	0.000	0.167
										6.250	0.000	6.250
										40 min. elapsed time		
2.0	Move the transport vehicle and cask to parking area and wait for washdown station. Hook up to car puller when ready.											
2.1	Move from inspection area to parking area.	0	YD	1	1	10	10 ^(a)	20	2	0.333	0.000	0.333
2.2	Unhook yard engine for wait.	2	YD	1	1	5	5 ^(a)	10	2	0.167	0.167	0.333
2.3	Wait for service line.	0		0	0	0	0	0	0	0.000	0.000	0.000
2.4	Hook up when ready.	2	YD	1	1	10	10 ^(a)	10	0.1	0.017	0.333	0.350
2.5	Move to washdown station.	0.1	YD	1	1	10	10 ^(a)	20	2	0.333	0.017	0.350

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Type	Total Number In Area	Number Doing Cask Work	In Minutes			In Area	Near Cask	Cask	Area
No.	Description											
2.6	Hook up to car puller.	0.1	YD	1	1	5	5 ^(a)	10	0.1	0.008	0.008	0.017
		0.1	M-C1	2	0	5	0			<u>0.000</u>	<u>0.017</u>	<u>0.017</u>
										0.858	0.542	1.400
										40 min. elapsed time		
3.0	Wash transport vehicle and cask, open personnel barrier, monitor, inspect and dry.											
3.1	Manual washdown.	0.1	OP2	1	1	20	20 ^(a)	6	10	3.333	0.033	3.367
		0.1	M-C1	2	2	20	0			0.000	0.067	0.067
3.2	Retract personnel barrier.	0.1	M-C1	2	2	10	10 ^(a)	10	5	1.667	0.033	1.700
	Perform security inspection	0.1	SG2	1	1	20	20 ^(a)	6	10	3.333	0.033	3.367
	and spot washdown of road	0.1	RM2	1	1	20	10	50	0	0.000	0.033	0.033
	dirt by wand if necessary.	0.1	OP2	1	1	20	20	6	10	3.333	0.033	3.367
	Complete radiation monitoring, drying.											
3.3	Cask drying.	0.1	--	0	0	15	15 ^(a)		0	<u>0.000</u>	<u>0.000</u>	<u>0.000</u>
										11.667	0.233	11.900
										55 min. elapsed time		
4.0	Move transport vehicle and cask to receiving and handling area.											
4.1	Move to receiving and handling area.	0.1	C0	1	1	5	5 ^(a)	30	1	<u>0.083</u>	<u>0.008</u>	<u>0.092</u>
										0.083	0.008	0.092
										5 min. elapsed time		
5.0	Prepare cask for removal from transport vehicle.											
5.1	Obtain and replace power hand tools.	0.1	M-C1	2	2	10	10 ^(a)	20	2	0.667	0.033	0.700

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Type	Total Number In Area	Number Doing Cask Work	In Minutes			In Area	Near Cask	Cask	Area
No.	Description											
5.2	Retrieve hook and grapples with crane, connect to impact limiter.	0.1	M-C1	2	2	10	10 ^(a)	20	2	0.667	0.033	0.700
		0.1	CO	1	1	10	10	30	1	0.167	0.017	0.183
5.3	Remove impact limiters, rm check, and place in setdown area (two trips required).	0.1	M-C1	2	2	45	45 ^(a)	3	20	30.000	0.150	30.150
		0.1	RM2	1	1	45	5	10	5	0.417	0.075	0.492
		0.1	CO	1	1	45	45	30	1	0.750	0.075	0.825
5.4	Remove cask tiedowns and prepare tilting cradle. lubricate trunnions.	0.1	M-C1	2	2	45	45 ^(a)	3	20	30.000	0.150	30.150
		0.1	CO	1	1	45	45	30	1	<u>0.750</u>	<u>0.075</u>	<u>0.825</u>
										63.417	0.608	64.025
										110 min. elapsed time		
6.0	Remove cask from transport vehicle, place on cask cart.											
6.1	Pick up cask lifting yoke with crane, travel to cask, position cask cart.	0.1	M-C1	2	2	10	10 ^(a)	20	2	0.667	0.033	0.700
		0.1	CO	1	1	10	10	30	1	0.167	0.017	0.183
6.2	Attach yoke to cask.	0.1	OP3	1	1	5	5 ^(a)	6	5	0.417	0.008	0.425
		0.1	CO	1	1	5	3	30	1	0.050	0.008	0.058
6.3	Upend cask and go to cart.	0.1	OP3	1	1	20	20 ^(a)	20	2	0.667	0.033	0.700
		0.1	CO	1	1	20	20	15	2	0.667	0.033	0.700
6.4	Put cask on cart.	0.1	OP3	1	1	10	10 ^(a)	15	5	0.833	0.017	0.850
		0.1	CO	1	1	10	10	15	2	0.333	0.017	0.350
6.5	Return yoke.	0.1	OP3	1	1	10	10 ^(a)	30	1	0.167	0.017	0.183
		0.1	CO	1	1	10	10	30	1	<u>0.167</u>	<u>0.017</u>	<u>0.183</u>
										4.133	0.200	4.333
										55 min. elapsed time		
7.0	Move cart and cask to cask handling room, close roll-up door to handling room.											
7.1	Move cart to cask handling room	0.1	OP3	1	1	5	5 ^(a)	10	5	<u>0.417</u>	<u>0.008</u>	<u>0.425</u>
										0.417	0.008	0.425
										5 min. elapsed time		

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Total Number In Area	Number Doing Cask Work	In Minutes	In Area			Near Cask	Cask	Area	Total
No.	Description		Type									
8.0	Prepare cask for unloading, position platform, install contamination barrier adapter, remove outer lid, pressure/gas sample cask cavity, remove inner lid bolts, install lid lifting adapter.											
8.1	Position platform.	0.1	RM2	1	1	5	5	10	5	0.417	0.008	0.425
		0.1	OP3	1	1	5	5	10	5	0.417	0.008	0.425
		0.1	M-C1	2	2	5	5(a)	10	5	0.833	0.017	0.850
8.2	Install contamination barrier adapter on the cask.	0.1	OP3	1	1	10	10	10	5	0.833	0.017	0.850
		0.1	M-C1	2	1	10	10(a)	3	30	5.000	0.033	5.033
8.3	Remove outer lid and place on platform.	0.1	M-C1	2	2	30	30(a)	3	80	80.000	0.100	80.100
		0.1	OP3	1	1	30	30	10	5	2.500	0.050	2.550
8.4	Pressure/gas sample cask cavity. Radiation monitor and QC check.	0.1	OP3	1	1	10	10(a)	4	100	16.667	0.017	16.683
		0.1	M-C1	2	2	10	10	10	5	1.667	0.033	1.700
		0.1	RM2	1	1	10	10	6	10	1.667	0.017	1.683
		0.1	QC1	1	1	10	10	6	10	1.667	0.017	1.683
8.5	Remove all but 4 bolts on inner lid.	0.1	M-C1	2	2	30	30(a)	3	200	200.000	0.100	200.100
		0.1	OP3	1	1	30	30	10	5	2.500	0.050	2.550
8.6	Install lifting lid adapter radiation monitor and QC check.	0.1	M-C1	2	2	5	5(a)	3	200	33.333	0.017	33.350
		0.1	OP3	1	1	5	5	10	5	0.417	0.008	0.425
		0.1	RM2	1	1	5	5	6	10	0.833	0.008	0.842
		0.1	QC1	1	1	5	5	6	10	0.833	0.008	0.842
									349.583	0.508	350.092	
									90 min. elapsed time			
9.1	Retract platform.	0.1	OP3	1	1	5	5	10	5	0.417	0.008	0.425
		0.1	M-C1	2	2	5	5(a)	10	5	0.833	0.017	0.850

Activity Steps		Area Dose Rate (mrem/hr)	Type	Staff		Activity Time In Minutes		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
No.	Description			Total Number In Area	Number Doing Cask Work	In Area	Near Cask			Cask	Area	Total
9.2	Move to cask unloading room.	0.1	OP3	1	1	5	5 ^(a)	10	5	<u>0.417</u>	<u>0.008</u>	<u>0.425</u>
										1.667	0.033	1.700
										10 min. elapsed time		
10.0	Mate the cask to the hot cell entry port. Close shielding door.											
10.1	Mate cask to hot cell entry port.	0.1	OP3	1	1	5	5 ^(a)	10	5	0.417	0.008	0.425
10.2	Close shadow shield.	0.1	OP3	1	1	5	5 ^(a)	10	5	0.417	0.008	0.425
10.3	Close shielding door.	0.1	OP3	1	1	5	5 ^(a)	20	2	<u>0.167</u>	<u>0.008</u>	<u>0.175</u>
										1.000	0.025	1.025
										15 min. elapsed time		
11.0	Using 20-ton hot cell crane, remove hot cell port plugs.											
11.1	20-ton crane picks up special grapple.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
11.2	Remove port plugs and set aside.	0.1	OP4	2		20 ^(a)				<u>0.000</u>	<u>0.067</u>	<u>0.067</u>
										0.000	0.083	0.083
										25 min. elapsed time		
12.0	Remove remaining inner lid bolts. Remove inner lid and spent fuel assembly spacer.											
12.1	Replace grapple with tool for bolt removal.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
12.2	Remove 4 bolts.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				0.000	0.025	0.025
12.3	Replace bolt tool with lid grapple. Remove lid, inspect, and set aside.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				0.000	0.025	0.025

B.8

Activity Steps		Area Dose Rate (mrem/hr)	Type	Staff		Activity Time In Minutes		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
				Total Number In Area	Number Doing Cask Work	In Area	Near Cask			Cask	Area	Total
12.4	Replace grapple for spent fuel, remove fuel spacer.	0.1	OP4	2		15 ^(a)				0.000	0.050	0.050
		0.1	QC2	1		15				0.000	0.025	0.025
										0.000	0.242	0.242
										50 min. elapsed time		
13.0	Unload csf canisters and place into in-cell lag storage.											
13.1	Unload csf canisters, place in lag storage after visually inspecting (15 min/canister).	0.1	OP4	2		420 ^(a)				0.000	1.400	1.400
		0.1	QC2	1		420				0.000	0.700	0.700
										0.000	2.100	2.100
										420 min. elapsed time		
14.0	Monitor and vacuum cask cavity and fuel basket.											
14.1	Replace grapple with vacuum device.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
		0.1	QC2	1		5				0.000	0.008	0.008
14.2	Vacuum cavities, lid, fuel spacer.	0.1	OP4	2		20 ^(a)				0.000	0.067	0.067
		0.1	QC2	1		20				0.000	0.033	0.033
14.3	Replace vacuum with survey tool.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
		0.1	QC2	1		5				0.000	0.008	0.008
14.4	Radiation survey of cask cavity and document.	0.1	OP4	2		60 ^(a)				0.000	0.200	0.200
		0.1	QC2	1		60				0.000	0.100	0.100
14.5	Replace survey tool with inspection device and inspect.	0.1	OP4	2		40 ^(a)				0.000	0.133	0.133
		0.1	QC2	1		40				0.000	0.067	0.067
										0.000	0.650	0.650
										130 min. elapsed time		
15.0	Replace spent fuel assembly spacer. Replace inner lid hot cell port plugs.											
15.1	Exchange inspection tool for fuel spacer/lid grapple.	0.1	OP4	2		5 ^(a)				0.000	0.017	0.017
		0.1	QC2	1		5				0.000	0.008	0.008
15.2	Replace fuel spacer and lid.	0.1	OP4	2		30 ^(a)				0.000	0.100	0.100
		0.1	QC2	1		30				0.000	0.050	0.050

[illegible]

B.9

B.10

No.	Activity Steps Description	Area Dose Rate (mrem/hr)	Staff			Activity Time In Minutes		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
			Type	Total Number In Area	Number Doing Cask Work	In Area	Near Cask			Cask	Area	Total
18.1	Install platform, and remove contamination barrier, adapter.	0.1	OP3	1	1	15	15	10	0	0.000	0.025	0.025
		0.1	RM2	1	1	15	15	10	0	0.000	0.025	0.025
		0.1	M-C1	2	2	15	15 ^(a)	3	0	0.000	0.050	0.050
18.2	Monitor and decontaminate external of cask as required.	0.1	RM2	1	1	40	40 ^(a)	2	0.2	0.133	0.067	0.200
		0.1	M-C1	2	2	40	40	10	0	0.000	0.133	0.133
		0.1	OP3	1	1	40	40	2	0.2	0.133	0.067	0.200
18.3	Remove lifting lid adapter.	0.1	M-C1	2	2	5	5 ^(a)	2	0.2	0.033	0.017	0.050
		0.1	OP3	1	1	5	5	10	0	0.000	0.008	0.008
18.4	Install inner lid bolts and verify torque.	0.1	M-C1	2	2	30	30 ^(a)	2	0.2	0.200	0.100	0.300
		0.1	OP3	1	1	30	30	10	0	0.000	0.050	0.050
		0.1	QC1	1	1	30	30	10	0	0.000	0.050	0.050
18.5	Secure all sample, flush, and drain ports.	0.1	OP3	1	1	10	10 ^(a)	2	0.2	0.033	0.017	0.050
		0.1	M-C1	2	2	10	10	10	0	0.000	0.033	0.033
18.6	Install outer lid and verify torque	0.1	M-C1	2	2	30	30 ^(a)	2	0.2	0.200	0.100	0.300
		0.1	OP3	1	1	30	30	10	0	0.000	0.050	0.050
		0.1	QC1	1	1	30	30	5	0.1	0.050	0.050	0.100
18.7	Remove platform.	0.1	OP3	1	1	5	5 ^(a)	10	0	0.000	0.008	0.008
		0.1	M-C1	2	0	5	5	10	0	<u>0.000</u>	<u>0.017</u>	<u>0.017</u>
										0.783	0.867	1.650
										135 min. elapsed time		
19.0	Move cask and cart to receiving and handling area.											
19.1	Move cart to receiving and inspection area.	0.1	OP3	1	1	5	5 ^(a)	30	0	<u>0.000</u>	<u>0.008</u>	<u>0.008</u>
										0.000	0.008	0.008
										5 min. elapsed time		
20.0	Place cask on the transport vehicle.											
20.1	Pick up cask lifting yoke with crane, travel to cask.	0.1	OP3	1	1	10	10 ^(a)	30	0	0.000	0.017	0.017
		0.1	CO	1	1	10	10	30	0	0.000	0.017	0.017

B.11

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)			
			Total Number In Area	Number Doing Cask Work	In Minutes	In Area			Near Cask	Cask	Area	Total
No.	Description		Type									
20.2	Attach yoke to cask.	0.1	OP3	1	1	5	5 ^(a)	6	0.1	0.008	0.008	0.017
		0.1	CO	1	1	5	5	30	0	0.000	0.008	0.008
20.3	Pick up cask.	0.1	OP3	1	1	10	5 ^(a)	10	0	0.000	0.017	0.017
		0.1	CO	1	1	10	10	30	0	0.000	0.017	0.017
20.4	Go to transport vehicle.	0.1	OP3	1	1	5	5 ^(a)	10	0	0.000	0.008	0.008
		0.1	CO	1	1	5	5	30	0	0.000	0.008	0.008
20.5	Put cask on vehicle and lay down, remove yoke.	0.1	OP3	1	1	20	20 ^(a)	10	0	0.000	0.033	0.033
		0.1	CO	1	1	20	20	30	0	<u>0.000</u>	<u>0.033</u>	<u>0.033</u>
										0.008	0.167	0.175
										50 min. elapsed time		
21.0	Prepare cask for shipment. Install cask tiedowns and impact limiters. Close personnel barrier.											
21.1	Install tiedowns.	0.1	M-C1	2	2	45	45 ^(a)	3	0.2	0.300	0.150	0.450
		0.1	CO	1	1	45	45	30	0	0.000	0.075	0.075
		0.1	RM2	1	1	45	5	3	0.2	0.017	0.075	0.092
		0.1	QC1	1	1	45	5	3	0.2	0.017	0.075	0.092
21.2	Install impact limiters.	0.1	M-C1	2	2	45	45 ^(a)	3	0.2	0.300	0.150	0.450
		0.1	CO	1	1	45	45	30	0	0.000	0.075	0.075
		0.1	RM2	1	1	45	5	3	0.2	0.017	0.075	0.092
		0.1	QC1	1	1	45	5	3	0.2	0.017	0.075	0.092
21.3	Close personnel barrier, monitor and install security seals.	0.1	M-C1	2	2	15	15 ^(a)	3	0	0.000	0.050	0.050
		0.1	CO	1	1	15	0	30	0	0.000	0.025	0.025
		0.1	RM2	1	1	15	10	3	0.2	0.033	0.025	0.058
		0.1	QC1	1	1	15	5	3	0.2	0.017	0.025	0.042
21.4	Disconnect from car puller, hook up yard tractor.	0.1	YD	1	1	10	10 ^(a)	10	0	0.000	0.017	0.017
										<u>0.717</u>	<u>0.892</u>	<u>1.608</u>
										115 min. elapsed time		

B.12

Activity Steps		Area Dose Rate (mrem/hr)	Staff		Activity Time		Work Distance from Cask In Feet	Dose Rate for Cask Work (mrem/hr)	Dose/Shipment (person-mrem)		
No.	Description		Type	Total Number In Area	Number Doing Cask Work	In Minutes In Area Near Cask			Cask	Area	Total
22.0	Move transport vehicle and cask to inspection area. Disconnect repository drive unit.										
22.1	Move transport vehicle by yard tractor to inspection area.	0.1	YD	1	1	20 20 ^(a)	20	0	0.000 0.000	0.033 0.033	0.033 0.033
								20 min. elapsed time			
23.0	Hook up over-the-road carrier. Move to gatehouse. Perform final monitoring and inspection of empty cask.										
23.1	Unhook yard engine.	0	YD	1	1	5 5 ^(a)	10	0	0.000	0.000	0.000
		0	ED	2	2	5 5	10	0	0.000	0.000	0.000
		0	SG2	1	1	5 5	10	0	0.000	0.000	0.000
23.2	Hook up engine and move to gatehouse.	0	YD	1	1	5 5 ^(a)	10	0	0.000	0.000	0.000
		0	ED	2	2	5 5	10	0	0.000	0.000	0.000
		0	SG2	1	1	5 5	10	0	0.000	0.000	0.000
23.3	Final monitoring and inspection.	0	ED	2	2	25 25	10	0	0.000	0.000	0.000
		0	RM1	1	1	25 25 ^(a)	3	0.2	0.083	0.000	0.083
		0	OP1	1	1	25 25	10	0	0.000	0.000	0.000
		0	SG1	1	1	25 25	10	0	0.000 0.083	0.000 0.000	0.000 0.083
											35 min. elapsed time
24.0	Notify appropriate organizations of the shipment departure.										
24.1	Notify organizations of shipment release - no exposure expected.	0	5	5 ^(a)					0.000 0.000	0.000 0.000	0.000 0.000
	Total elapsed time = 1515 min.							Total	440.667	7.642	448.308
									5 min. elapsed time		

(a) Indicates critical activity that controls the elapsed time of that activity.

APPENDIX C

IN-TRANSIT DOSE CALCULATIONS

APPENDIX C

IN-TRANSIT DOSE CALCULATIONS

This appendix contains the detailed spreadsheets used to calculate in-transit radiation doses to the public and workers. The exposure times, dose rates, and numbers of exposed persons are, for the most part, identical to those derived in DOE (1987a). The primary differences between DOE (1987a) and this analysis are:

- differences in shipping distances and number of shipments that arise from analyzing a system with an MRS vs. without an MRS
- the addition of a spreadsheet to calculate in-transit doses for dedicated train shipments.

This appendix presents the in-transit radiation dose calculations from 14 spreadsheets. There are seven spreadsheets for the different potential shipment types in a system with an eastern MRS and seven for the western MRS. The seven spreadsheets for each MRS location include truck and rail shipments from eastern reactors, truck and rail shipments from western reactors, and three potential dedicated train configurations for shipments from the MRS (one in which fuel is consolidated and the hardware is packaged in canisters, one in which the hardware is packaged in drums, and one in which the fuel is not consolidated). Two tables are provided for each potential shipment type: a table that contains the detailed spreadsheet and a summary table. Therefore, a total of 28 tables are presented in this appendix. These 28 tables are summarized as follows:

- Table C.1 Detailed, Truck from Eastern Reactors to an Eastern MRS
- Table C.2 Summary, Truck from Eastern Reactors to Eastern MRS
- Table C.3 Detailed, Truck from Eastern Reactors to Western MRS
- Table C.4 Summary, Truck from Eastern Reactors to Western MRS
- Table C.5 Detailed, Truck from Western Reactors to Repository

- Table C.6 Summary, Truck from Western Reactors to Repository
- Table C.7 Detailed, Truck from Western Reactors to Western MRS
- Table C.8 Summary, Truck from Western Reactors to Western MRS
- Table C.9 Detailed, GFR^(a) from Eastern Reactors to Eastern MRS
- Table C.10 Summary, GFR from Eastern Reactors to Eastern MRS
- Table C.11 Detailed, GFR from Eastern Reactors to Western MRS
- Table C.12 Summary, GFR from Eastern Reactors to Western MRS
- Table C.13 Detailed, GFR from Western Reactors to Repository
- Table C.14 Summary, GFR from Western Reactors to Repository
- Table C.15 Detailed, GFR from Western Reactors to Western MRS
- Table C.16 Summary, GFR from Western Reactors to Western MRS
- Table C.17 Detailed, Dedicated Train Shipments, Consolidated Fuel, Hardware in Canisters (Eastern MRS)
- Table C.18 Summary, Dedicated Train, Consolidated Fuel, Hardware in Canisters (Eastern MRS)
- Table C.19 Detailed, Dedicated Train, Consolidated Fuel, Hardware in Drums (Eastern MRS)
- Table C.20 Summary, Dedicated Train, Consolidated Fuel, Hardware in Drums (Eastern MRS)
- Table C.21 Detailed, Dedicated Train, Unconsolidated Fuel (Eastern MRS)
- Table C.22 Summary, Dedicated Train, Unconsolidated Fuel (Eastern MRS)
- Table C.23 Detailed, Dedicated Train, Consolidated Fuel, Hardware in Canisters (Western MRS)
- Table C.24 Summary, Dedicated Train, Consolidated Fuel, Hardware in Canisters (Western MRS)
- Table C.25 Detailed, Dedicated Train, Consolidated Fuel, Hardware in Drums (Western MRS)

(a) GFR = General Freight Rail.

- Table C.26 Summary, Dedicated Train, Consolidated Fuel, Hardware In Drums (Western MRS)
- Table C.27 Detailed, Dedicated Train, Unconsolidated Fuel (Western MRS)
- Table C.28 Summary, Dedicated Train, Unconsolidated Fuel (Western MRS)

TABLE C.1. In-Transit Dose Calculations for Truck Shipments from Eastern Reactors to an Eastern MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	800.00	PWR	0.93	606.00	Shipments/yr	
		Suburban	500.00	BWR	0.93	188.00		857.00
		Urban	13.00					

Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Drivers								
- While moving	2.00	10	Top	2.00	23.04			92.17
- At stops								
Near cask	2.00	10	Top	0.60	7.22			8.67
Away cask	2.00	20	Side	0.18	7.22			<u>2.60</u>
								11.27
Escorts								
- While moving								
In front	2.00	50	Top	0.02	0.54			0.02
Behind	2.00	50	Bottom	0.01	0.54			<u>0.01</u>
								0.03
- At stops	4.00	20	Side	0.18	3.00			<u>2.16</u>
								2.19
Service Station Attendant								
Near Cask	1.00	10	Top	0.60	0.67			0.40
Away Cask	1.00	20	Side	0.18	2.33			<u>0.42</u>
								0.82
State Inspectors								
Near Cask	2.00	5	Side	3.20	2.00			12.80
Away Cask	0.00							<u>0.00</u>
								12.80
General population								
- While moving								
Passing vehicles								
Rural						3.10E-06	800.00	2.48
Suburban						4.00E-05	500.00	20.00
Urban						1.40E-04	13.00	<u>1.82</u>
								24.30
Population along route								
Rural						1.70E-07	800.00	0.14
Suburban						3.90E-05	500.00	19.50
Urban						2.10E-05	13.00	<u>0.27</u>
								19.91
- At stops						1.40E-04	1313.00	183.82
TOTAL								346.45

Not including service attendants

TABLE C.2. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Eastern Reactors to an Eastern MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
- Drivers	103.43	111.70	88.69	2585.81
- Escorts	2.19	2.36	1.88	117.76
- Attendants ^(d)	0.82	0.89	0.70	87.74
- Inspectors	<u>12.80</u>	<u>13.82</u>	<u>10.98</u>	<u>684.80</u>
Total Transport Workers	118.42	127.88	101.54	NA
Public	<u>228.03</u>	<u>246.25</u>	<u>195.52</u>	<u>57.78/2.43^(e)</u>
Grand Total		346.45	374.13	297.06 NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.1.

(d) Not included in totals.

(e) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.3. In-Transit Dose Calculations for Truck Shipments from Eastern Reactors to a Western MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr		Total
		Rural	2670.00	PWR	0.93	606.00		Shipments/yr
		Suburban	600.00	BWR	0.93	188.00		858.00
		Urban	33.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Drivers								
- While moving	2.00	10	Top	2.00	49.75			199.00
- At stops								
Near cask	2.00	10	Top	0.60	18.17			21.80
Away cask	2.00	20	Side	0.18	18.17			<u>6.54</u>
								28.34
Escorts								
- While moving								
In front	2.00	50	Top	0.02	1.38			0.05
Behind	2.00	50	Bottom	0.01	1.38			<u>0.02</u>
								0.07
- At stops	4.00	20	Side	0.18	3.00			<u>2.16</u>
								2.23
Service Station Attendant								
Near Cask	1.00	10	Top	0.60	2.01			1.21
Away Cask	1.00	20	Side	0.18	6.99			<u>1.26</u>
								2.46
State Inspectors								
Near Cask	2.00	5	Side	3.20	2.00			12.80
Away Cask	0.00							<u>0.00</u>
								12.80
General population								
- While moving								
Passing vehicles								
Rural						3.10E-06	2670.00	8.28
Suburban						4.00E-05	600.00	24.00
Urban						1.40E-04	33.00	<u>4.62</u>
								36.90
Population along route								
Rural						1.70E-07	2670.00	0.45
Suburban						3.90E-05	600.00	23.40
Urban						2.10E-05	33.00	<u>0.69</u>
								24.55
- At stops						1.40E-04	3303.00	462.42
TOTAL								766.23

Not including service attendants

TABLE C.4. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Eastern Reactors to a Western MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
- Drivers	227.34	246.04	195.06	2955.42
- Escorts	2.23	2.41	1.91	121.72
- Attendants ^(d)	2.46	2.67	2.11	87.74
- Inspectors	12.80	13.85	10.98	688.00
Total Transport Workers	242.37	262.30	207.95	NA
Public	<u>523.86</u>	<u>566.95</u>	<u>449.47</u>	<u>57.78/2.43^(e)</u>
Grand Total	766.23	829.26	657.42	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.3.

(d) Not included in totals.

(e) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.5. In-Transit Dose Calculations for Truck Shipments From Western Reactors to the Yucca Mountain Repository

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	1300.00	PWR	0.93	165.00	Shipments/yr	
		Suburban	250.00	BWR	0.93	45.00		227.00
		Urban	16.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Drivers								
- While moving	2.00	10	Top	2.00	23.17			92.67
- At stops								
Near cask	2.00	10	Top	0.60	8.61			10.34
Away cask	2.00	20	Side	0.18	8.61			3.10
								13.44
Escorts								
- While moving								
In front	2.00	50	Top	0.02	0.67			0.03
Behind	2.00	50	Bottom	0.01	0.67			0.01
								0.03
- At stops	4.00	20	Side	0.18	3.00			2.16
								2.19
Service Station Attendant								
Near Cask	1.00	10	Top	0.60	1.34			0.80
Away Cask	1.00	20	Side	0.18	4.66			0.84
								1.64
State Inspectors								
Near Cask	2.00	5	Side	3.20	2.00			12.80
Away Cask	0.00							0.00
								12.80
General population								
- While moving								
Passing vehicles								
Rural						3.10E-06	1300.00	4.03
Suburban						4.00E-05	250.00	10.00
Urban						1.40E-04	16.00	2.24
								16.27
Population along route								
Rural						1.70E-07	1300.00	0.22
Suburban						3.90E-05	250.00	9.75
Urban						2.10E-05	16.00	0.34
								10.31
- At stops						1.40E-04	1566.00	219.24
TOTAL								366.91
Not including service attendants								

C.0

TABLE C.6. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Western Reactors to the Yucca Mountain Repository

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
- Drivers	106.10	114.83	24.08	2546.47
- Escorts	2.19	2.37	0.50	31.50
- Attendants ^(d)	1.64	1.78	0.37	22.96
- Inspectors	<u>12.80</u>	<u>13.85</u>	<u>2.91</u>	<u>182.40</u>
Total Transport Workers	121.10	131.06	27.48	NA
Public	<u>245.82</u>	<u>266.04</u>	<u>55.79</u>	<u>57.12/0.64^(e)</u>
Grand Total	366.91	397.09	83.27	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.5.

(d) Not included in totals.

(e) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.7. In-Transit Dose Calculations for Truck Shipments from Western Reactors to a Western MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total Shipments/yr	
		Rural	1737.00	PWR	0.92	165.00		
		Suburban	367.00	BWR	0.93	45.00		
		Urban	18.00					227.00

Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Drivers								
- While moving	2.00	10	Top	2.00	31.64			126.55
- At stops								
Near cask	2.00	10	Top	0.60	11.67			14.01
Away cask	2.00	20	Side	0.18	11.67			4.20
								18.21
Escorts								
- While moving								
In front	2.00	50	Top	0.02	0.75			0.03
Behind	2.00	50	Bottom	0.01	0.75			0.01
								0.04
- At stops	4.00	20	Side	0.18	3.00			2.16
Service Station Attendant								
Near Cask	1.00	10	Top	0.60	1.34			0.80
Away Cask	1.00	20	Side	0.18	4.66			0.84
								1.64
State Inspectors								
Near Cask	2.00	5	Side	3.20	2.00			12.80
Away Cask	0.00							0.00
								12.80
General population								
- While moving								
Passing vehicles								
Rural						3.10E-06	1737.00	5.38
Suburban						4.00E-05	367.00	14.68
Urban						1.40E-04	18.00	2.52
								22.58
Population along route								
Rural						1.70E-07	1737.00	0.30
Suburban						3.90E-05	367.00	14.31
Urban						2.10E-05	18.00	0.38
								14.99
- At stops						1.40E-04	2122.00	297.08
TOTAL								494.41

Not including service attendants

TABLE C.8. Summary of Estimated In-Transit Radiation Doses for Truck Shipments from Western Reactors to a Western MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
- Drivers	144.76	156.66	32.85	2750.38
- Escorts	2.20	2.38	0.50	31.59
- Attendants ^(d)	1.64	1.78	0.37	22.96
- Inspectors	<u>12.80</u>	<u>13.85</u>	<u>2.91</u>	<u>182.40</u>
Total Transport Workers	159.75	172.89	36.26	NA
Public	<u>334.65</u>	<u>362.18</u>	<u>75.95</u>	<u>57.12/0.64^(e)</u>
Grand Total	494.41	535.07	112.21	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.7.

(d) Not included in totals.

(e) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.9. In-Transit Dose Calculations for GFR Shipments from Eastern Reactors to an Eastern MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	1034.00		PWR	6.47	986.00	
		Suburban	530.00		BWR	6.70	870.00	
		Urban	34.00					282.00
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	150	Top	0.0021	49.94			0.52
- At stops								
Crew	5.00	150	Top	0.0021	112.73			1.18
Handlers	10.00	10	Side	0.7600	0.98			7.41
Yard Crew	100.00	200	Side	0.0013	112.73			14.66
								23.25
Escorts								
- While moving								
In front	2.00	50	Top	0.0600	49.94			5.99
Behind	0.00	50	Bottom	0.0060	1.20			0.00
								5.99
- At stops								
Near Cask	2.00	50	Top	0.0600	112.73			13.53
Away Cask								0.00
								13.53
State Inspectors								
Near Cask	4.00	10	Side	0.7600	0.50			1.52
Away Cask	0.00							0.00
								1.52
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	1034.00	0.04
Suburban						4.80E-07	530.00	0.25
Urban						1.30E-06	34.00	0.04
								0.34
Population along route								
Rural						1.90E-07	1034.00	0.20
Suburban						3.20E-05	530.00	16.96
Urban						6.00E-06	34.00	0.20
								17.36
- At stops	240.00	300	Side	0.0006	112.73			14.88
TOTAL								77.40

TABLE C.10. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Eastern Reactors to an Eastern MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>			<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>	<u>Annual Dose, Person-rem/yr^(c)</u>	
Transport Workers				
Train crew	1.71	0.26	0.48	1.76
Handlers	7.41	1.15	2.09	10.72
Yard crew	14.66	2.27	4.14	1.10
Escorts	19.52	3.02	5.51	101.52
Inspectors	<u>1.52</u>	<u>0.23</u>	<u>0.43</u>	<u>26.79</u>
C.13 Total Transport Workers	44.82	6.93	12.65	NA
Public	<u>32.58</u>	<u>5.04</u>	<u>9.20</u>	<u>3.10/1.42^(d)</u>
Grand Total	77.40	11.96	21.84	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.9.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.11. In-Transit Dose Calculations for GFR Shipments from Eastern Reactors to a Western MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	2660.00	PWR	6.47	986.00	Shipments/yr	
		Suburban	630.00	BWR	6.70	870.00		282.00
		Urban	33.00					

Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	150	Top	0.0021	103.84			1.09
- At stops								
Crew	5.00	150	Top	0.0021	169.66			1.78
Handlers	10.00	10	Side	0.7600	1.60			12.13
Yard Crew	100.00	200	Side	0.0013	169.66			22.06
								35.97
Escorts								
- While moving								
In front	2.00	50	Top	0.0600	103.84			12.46
Behind	0.00	50	Bottom	0.0060	1.20			0.00
								12.46
- At stops								
Near Cask	2.00	50	Top	0.0600	169.66			20.36
Away Cask								0.00
								20.36
State Inspectors								
Near Cask	4.00	10	Side	0.7600	0.50			1.52
Away Cask	0.00							0.00
								1.52
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	2660.00	0.10
Suburban						4.80E-07	630.00	0.30
Urban						1.30E-06	33.00	0.04
								0.45
Population along route								
Rural						1.90E-07	2660.00	0.20
Suburban						3.20E-05	630.00	20.16
Urban						6.00E-06	33.00	0.20
								20.86
- At stops	240.00	300	Side	0.0006	169.66			22.39
TOTAL								115.10

C.14

TABLE C.12. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Eastern Reactors to a Western MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
Train crew	2.87	0.44	0.81	1.76
Handlers	12.13	1.88	3.42	10.72
Yard crew	22.06	3.41	6.23	1.10
Escorts	32.82	5.07	9.26	101.52
Inspectors	<u>1.52</u>	<u>0.23</u>	<u>0.43</u>	<u>26.79</u>
C.15 Total Transport Workers	71.40	11.04	20.15	NA
Public	<u>43.70</u>	<u>6.75</u>	<u>12.34</u>	<u>3.10/1.42^(d)</u>
Grand Total	115.10	17.79	32.49	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 0.93 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.11.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.13. In-Transit Dose Calculations for GFR Shipments from Western Reactors to the Yucca Mountain Repository

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	1510.00				Shipments/yr	
		Suburban	150.00	PWR	6.47	140.00		
		Urban	34.00	BWR	6.70	0.00		22.00

Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	150	Top	0.0021	52.94			0.56
- At stops								
Crew	5.00	150	Top	0.0021	115.90			1.22
Handlers	10.00	10	Side	0.7600	1.01			7.67
Yard Crew	100.00	200	Side	0.0013	115.90			15.07
								<u>23.96</u>
Escorts								
- While moving								
In front	2.00	50	Top	0.0600	52.94			6.35
Behind	0.00	50	Bottom	0.0060	1.20			0.00
								<u>6.35</u>
- At stops								
Near Cask	2.00	50	Top	0.0600	115.90			13.91
Away Cask								0.00
								<u>13.91</u>
State Inspectors								
Near Cask	4.00	10	Side	0.7600	0.50			1.52
Away Cask	0.00							0.00
								<u>1.52</u>
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	1510.00	0.06
Suburban						4.80E-07	150.00	0.07
Urban						1.30E-06	34.00	0.04
								<u>0.17</u>
Population along route								
Rural						1.90E-07	1510.00	0.29
Suburban						3.20E-05	150.00	4.80
Urban						6.00E-06	34.00	0.20
								<u>5.29</u>
- At stops	240.00	300	Side	0.0006	115.90			15.30
TOTAL								65.06

TABLE C.14. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Western Reactors to the Yucca Mountain Repository

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>		<u>Annual Dose, Person-rem/yr^(c)</u>	<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>		
Transport Workers				
Train crew	1.77	0.27	0.04	0.14
Handlers	7.67	1.19	0.17	0.84
Yard crew	15.07	2.33	0.33	0.09
Escorts	20.26	3.13	0.44	7.92
Inspectors	<u>1.52</u>	<u>0.23</u>	<u>0.03</u>	<u>2.09</u>
C.17 Total Transport Workers	46.30	7.16	1.00	NA
Public	<u>20.76</u>	<u>3.21</u>	<u>0.45</u>	<u>0.24/0.11^(d)</u>
Grand Total	67.06	10.36	1.45	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 6.47 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.13.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.15. In-Transit Dose Calculations for GFR Shipments from Western Reactors to a Western MRS

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Total	
		Rural	2092.00		PWR	6.47	140.00	Shipments/yr
		Suburban	223.00		BWR	6.70	0.00	22.00
		Urban	35.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	150	Top	0.0021	73.44			0.77
- At stops								
Crew	5.00	150	Top	0.0021	137.55			1.44
Handlers	10.00	10	Side	0.7600	1.25			9.47
Yard Crew	100.00	200	Side	0.0013	137.55			17.88
								28.80
Escorts								
- While moving								
In front	2.00	50	Top	0.0600	73.44			8.81
Behind	0.00	50	Bottom	0.0060	1.20			0.00
								8.81
- At stops								
Near Cask	2.00	50	Top	0.0600	137.55			16.51
Away Cask								0.00
								16.51
State Inspectors								
Near Cask	4.00	10	Side	0.7600	0.50			1.52
Away Cask	0.00							0.00
								1.52
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	2092.00	0.08
Suburban						4.80E-07	223.00	0.11
Urban						1.30E-06	35.00	0.05
								0.23
Population along route								
Rural						1.90E-07	2092.00	0.40
Suburban						3.20E-05	223.00	7.14
Urban						6.00E-06	35.00	0.21
								7.74
- At stops	240.00	300	Side	0.0006	137.55			18.16
TOTAL								82.54

TABLE C.16. Summary of Estimated In-Transit Radiation Doses for GFR Shipments from Western Reactors to a Western MRS

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>			<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>	<u>Annual Dose, Person-rem/yr^(c)</u>	
Transport Workers				
Train crew	2.22	0.34	0.05	0.14
Handlers	9.47	1.46	0.20	0.84
Yard crew	17.88	2.76	0.39	0.09
Escorts	25.32	3.91	0.55	7.92
Inspectors	<u>1.52</u>	<u>0.23</u>	<u>0.03</u>	<u>2.09</u>
C.19 Total Transport Workers	56.40	8.72	1.22	NA
Public	<u>26.13</u>	<u>4.04</u>	<u>0.57</u>	<u>0.24/0.11^(d)</u>
Grand Total	82.54	12.76	1.79	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 6.47 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.13.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.17. In-Transit Dose Calculations for Dedicated Train Shipments of Consolidated Fuel with Hardware in Canisters (Eastern MRS)

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Cars/train	Total
		Rural	2023.00	PWR	129.36	1592.00	9.00	Shipments/yr
		Suburban	282.00	BWR	130.20	1058.00		20.00
		Urban	47.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	30	Top	0.07	73.50			25.73
- At stops								
Crew	5.00	30	Top	0.07	11.41			3.99
Handlers	3.00	10	Side	0.76	4.67			10.66
Yard Crew	100.00	100	Side	0.01	6.23	1.60E-06		8.98
					stops/trip	rem/person per stop		49.35
Escorts								
- While moving								
In front	2.00	30	Bottom	0.19	73.50			27.93
- At stops								
Near Cask	2.00	30	Bottom	0.19	11.41			4.34
								32.27
State Inspectors								
Near Cask	2.00	10	Side	0.76	3.00			4.56
Away Cask	0.00							0.00
								4.56
							Subtotal: Workers	86.17
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	2023.00	0.69
Suburban						4.80E-07	282.00	1.22
Urban						1.30E-06	47.00	0.55
								2.46
Population along route								
Rural						1.90E-07	2023.00	3.46
Suburban						3.20E-05	282.00	81.22
Urban						6.00E-06	47.00	2.54
								87.21
- At stops	240.00	300	Side	0.00	11.41	0.37	person-mrem/hr	4.22
							Subtotal: Public	93.89
TOTAL								180.06

C.20

TABLE C.18. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Consolidated Fuel; Hardware in Canisters (Eastern MRS)

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>			<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>	<u>Annual Dose, Person-rem/yr^(c)</u>	
Transport Workers				
Train crew	29.72	0.23	0.61	16.80
Handlers	10.66	0.08	0.22	2.85
Yard crew	8.98	0.07	0.18	0.28
Escorts	32.27	0.25	0.66	45.60
Inspectors	<u>4.56</u>	<u>0.04</u>	<u>0.09</u>	<u>11.40</u>
C.21 Total Transport Workers	86.17	0.67	1.76	NA
Public	<u>93.89</u>	<u>0.73</u>	<u>1.92</u>	<u>0.20/0.90^(d)</u>
Grand Total	180.06	1.39	3.68	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 6.47 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.17.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.19. In-Transit Dose Calculations for Dedicated Train Shipments of Consolidated Fuel with Hardware in Drums (Eastern MRS)

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Cars/train	Total	
		Rural	2023.00	PWR	129.36	1592.00	10.00	Shipments/yr	
		Suburban	282.00	BWR	130.20	1058.00			20.00
		Urban	47.00						
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem	
Train/Railroad Crews									
- While moving	5.00	30	Top	0.07	73.50				25.73
- At stops									
Crew	5.00	30	Top	0.07	11.41				3.99
Handlers	10.00	10	Side	0.76	5.19				11.84
Yard Crew	100.00	100	Side	0.01	6.23	1.60E-06			9.97
					stops/trip	rem/person per stop			51.53
Escorts									
- While moving									
In front	2.00	30	Bottom	0.19	73.50				27.93
- At stops									
Near Cask	2.00	30	Bottom	0.19	11.41				4.34
									32.27
State Inspectors									
Near Cask	2.00	10	Side	0.76	3.33				5.06
Away Cask	0.00								0.00
									5.06
							Subtotal: Workers		88.86
General population									
- While moving									
Passing vehicles									
Rural						3.80E-08	2023.00		0.77
Suburban						4.80E-07	282.00		1.35
Urban						1.30E-06	47.00		0.61
									2.73
Population along route									
Rural						1.90E-07	2023.00		3.84
Suburban						3.20E-05	282.00		90.24
Urban						6.00E-06	47.00		2.82
									96.90
- At stops	240.00	300	Side	0.00	11.41	0.37 person-mrem/hr			4.22
							Subtotal: Public		103.86
TOTAL									192.72

TABLE C.20. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Consolidated Fuel; Hardware in Drums (Eastern MRS)

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>			<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>	<u>Annual Dose, Person-rem/yr^(c)</u>	
Transport Workers				
Train crew	29.72	0.23	0.61	16.80
Handlers	11.84	0.09	0.24	2.85
Yard crew	9.97	0.08	0.20	0.28
Escorts	32.27	0.25	0.66	45.60
Inspectors	<u>5.06</u>	<u>0.04</u>	<u>0.10</u>	<u>11.40</u>
C.23 Total Transport Workers	88.86	0.69	1.82	NA
Public	<u>103.86</u>	<u>0.80</u>	<u>2.12</u>	<u>0.20/0.90^(d)</u>
Grand Total	192.72	1.49	3.94	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 6.47 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.19.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.21. In-Transit Dose Calculations for Dedicated Train Shipments of Unconsolidated Fuel (Eastern MRS)

INPUT DATA		Shipping Distance, km				MTU/shipment		MTU/yr	Cars/train	Total
		Rural	2023.00			PWR	64.68	1592.00	6.00	Shipments/yr
		Suburban	282.00			BWR	56.73	1058.00		43.00
		Urban	47.00							
Population Subgroup		Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem	
Train/Railroad Crews										
- While moving	5.00	30	Top	0.07	73.50					25.73
- At stops										
Crew	5.00	30	Top	0.07	11.41					3.99
Handlers	3.00	10	Side	0.76	3.12					7.10
Yard Crew	100.00	100	Side	0.01	6.23		1.60E-06			5.98
					stops/trip		rem/person per stop			42.81
Escorts										
- While moving										
In front	2.00	30	Bottom	0.19	73.50					27.93
- At stops										
Near Cask	2.00	30	Bottom	0.19	11.41					4.34
										32.27
State Inspectors										
Near Cask	2.00	10	Side	0.76	2.00					3.04
Away Cask	0.00									0.00
										3.04
								Subtotal: Workers		78.11
General population										
- While moving										
Passing vehicles										
Rural							3.80E-08	2023.00		0.46
Suburban							4.80E-07	282.00		1.81
Urban							1.30E-06	47.00		0.37
										1.64
Population along route										
Rural							1.90E-07	2023.00		2.31
Suburban							3.20E-05	282.00		54.14
Urban							6.00E-06	47.00		1.69
										58.14
- At stops	240.00	300	Side	0.00	11.41			0.37 person-mrem/hr		4.22
									Subtotal: Public	64.00
TOTAL										142.11

C.24

TABLE C.22. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Unconsolidated Fuel (Eastern MRS)

<u>Population Subgroup</u>	<u>Collective Dose^(a)</u>			<u>Dose to Maximally Exposed Individual, mrem/yr</u>
	<u>Per-Shipment Dose Person-mrem</u>	<u>Person-mrem per MTU^(b)</u>	<u>Annual Dose, Person-rem/yr^(c)</u>	
Transport Workers				
Train crew	29.72	0.46	1.29	36.12
Handlers	7.10	0.11	0.31	6.27
Yard crew	5.98	0.09	0.26	0.60
Escorts	32.27	0.50	1.40	98.04
Inspectors	<u>3.04</u>	<u>0.05</u>	<u>0.13</u>	<u>24.51</u>
Total Transport Workers	78.11	1.21	3.38	NA
Public	<u>64.00</u>	<u>0.99</u>	<u>2.77</u>	<u>0.43/1.94^(d)</u>
Grand Total	142.11	10.36	1.45	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 6.47 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.21.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.23. In-Transit Dose Calculations for Dedicated Train Shipments of Consolidated Fuel with Hardware in Canisters (Western MRS)

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Cars/train	Total
		Rural	1074.00	PWR	129.36	1897.00	9.00	Shipments/yr
		Suburban	134.00	BWR	130.20	1103.00		23.00
		Urban	12.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	30	Top	0.07	38.13			13.34
- At stops								
Crew	5.00	30	Top	0.07	6.88			2.41
Handlers	3.00	10	Side	0.76	3.15			7.17
Yard Crew	100.00	100	Side	0.01	4.20	1.60E-06		6.04
					stops/trip	rem/person per stop		28.97
Escorts								
- While moving								
In front	2.00	30	Bottom	0.19	38.13			14.49
- At stops								
Near Cask	2.00	30	Bottom	0.19	6.88			2.61
								17.10
State Inspectors								
Near Cask	2.00	10	Side	0.76	3.00			4.56
Away Cask	0.00							0.00
								4.56
							Subtotal: Workers	50.62
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	1074.00	0.37
Suburban						4.80E-07	134.00	0.58
Urban						1.30E-06	12.00	0.14
								1.09
Population along route								
Rural						1.90E-07	1074.00	1.84
Suburban						3.20E-05	134.00	38.59
Urban						6.00E-06	12.00	0.65
								41.08
- At stops	240.00	300	Side	0.00	6.88	0.37 person-mrem/hr		2.55
							Subtotal: Public	44.71
TOTAL								95.33

TABLE C.24. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Consolidated Fuel; Hardware in Canisters (Western MRS)

Population Subgroup	Collective Dose ^(a)			Dose to Maximally Exposed Individual, mrem/yr
	Per-Shipment Dose Person-mrem	Person-mrem per MTU ^(b)	Annual Dose, Person-rem/yr ^(c)	
Transport Workers				
Train crew	15.75	0.12	0.36	19.32
Handlers	7.17	0.06	0.17	3.42
Yard crew	6.04	0.05	0.14	0.32
Escorts	17.10	0.13	0.40	52.44
Inspectors	<u>4.56</u>	<u>0.04</u>	<u>0.11</u>	<u>13.11</u>
C.27 Total Transport Workers	50.62	0.39	1.17	NA
Public	<u>44.71</u>	<u>0.35</u>	<u>1.03</u>	<u>0.23/1.04^(d)</u>
Grand Total	95.33	0.74	2.21	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 129.36 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.23.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.25. In-Transit Dose Calculations for Dedicated Train Shipments of Consolidated Fuel with Hardware in Drums (Western MRS)

INPUT DATA		Shipping Distance, km		MTU/shipment		MTU/yr	Cars/train	Total
		Rural	1074.00	PWR	129.36	1897.00	10.00	Shipments/yr
		Suburban	134.00	BWR	130.20	1103.00		23.00
		Urban	12.00					
Population Subgroup	Number of Individuals	Average Distance From Cask, m	Orientation	Dose Rate, mrem/hr	Exposure Time, hr	Dose Factor Person-rem/km	Shipping Distance, km	Subtotals, Per Shipment Dose, Person-mrem
Train/Railroad Crews								
- While moving	5.00	30	Top	0.07	38.13			13.34
- At stops								
Crew	5.00	30	Top	0.07	6.88			2.41
Handlers	3.00	10	Side	0.76	3.50			7.97
Yard Crew	100.00	100	Side	0.01	4.20	1.60E-06		6.71
					stops/trip	rem/person per stop		30.43
Escorts								
- While moving								
In front	2.00	30	Bottom	0.19	38.13			14.49
- At stops								
Near Cask	2.00	30	Bottom	0.19	6.88			2.61
								17.10
State Inspectors								
Near Cask	2.00	10	Side	0.76	3.33			5.06
Away Cask	0.00							0.00
								5.06
							Subtotal: Workers	52.60
General population								
- While moving								
Passing vehicles								
Rural						3.80E-08	1074.00	0.41
Suburban						4.80E-07	134.00	0.64
Urban						1.30E-06	12.00	0.16
								1.21
Population along route								
Rural						1.90E-07	1074.00	2.04
Suburban						3.20E-05	134.00	42.88
Urban						6.00E-06	12.00	0.72
								45.64
- At stops	240.00	300	Side	0.00	6.88	0.37 person-mrem/hr		2.55
							Subtotal: Public	49.39
TOTAL								101.99

TABLE C.26. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Consolidated Fuel; Hardware in Drums (Western MRS)

Population Subgroup	Collective Dose ^(a)			Dose to Maximally Exposed Individual, mrem/yr
	Per-Shipment Dose Person-mrem	Person-mrem per MTU ^(b)	Annual Dose, Person-rem/yr ^(c)	
Transport Workers				
Train crew	15.75	0.12	0.36	19.32
Handlers	7.97	0.06	0.18	3.42
Yard crew	6.71	0.05	0.16	0.32
Escorts	17.10	0.13	0.40	52.44
Inspectors	<u>5.06</u>	<u>0.04</u>	<u>0.12</u>	<u>13.11</u>
C.29 Total Transport Workers	52.60	0.41	1.22	NA
Public	<u>49.39</u>	<u>0.38</u>	<u>1.14</u>	<u>0.23/1.04^(d)</u>
Grand Total	101.99	0.79	2.36	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 129.36 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.25.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

TABLE C.28. Summary of Estimated In-Transit Radiation Doses for Dedicated Train Shipments of Unconsolidated Fuel (Western MRS)

Population Subgroup	Collective Dose ^(a)			Dose to Maximally Exposed Individual, mrem/yr
	Per-Shipment Dose Person-mrem	Person-mrem per MTU ^(b)	Annual Dose, Person-rem/yr ^(c)	
Transport Workers				
Train crew	15.75	0.24	0.77	41.16
Handlers	4.78	0.07	0.23	6.84
Yard crew	4.03	0.06	0.20	0.69
Escorts	17.10	0.26	0.83	111.72
Inspectors	<u>3.04</u>	<u>0.05</u>	<u>0.15</u>	<u>27.93</u>
C.31 Total Transport Workers	44.70	0.69	2.18	NA
Public	<u>30.65</u>	<u>0.47</u>	<u>1.50</u>	<u>0.49/2.21^(d)</u>
Grand Total	75.35	1.17	3.68	NA

NA = Not Applicable

(a) Columns may not sum correctly because of round-off.

(b) Based on 64.68 MTU PWR fuel per shipment.

(c) Based on annual shipment quantities given in Table C.27.

(d) First value is the maximum public exposure at stops. The second value is the maximum public exposure to persons residing near the transport route.

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