RADIATION DOSES RESULTING FROM VARIATIONS IN SPENT FUEL/WASTE

MANAGEMENT SYSTEMS WITHOUT MONITORED RETRIEVABLE STORAGE

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ABSTRACT

This paper presents results of analyses of radiological dose impacts on the public and the workers of nine potential transportation-related changes in the operation of a hypothetical high-level waste management system that does not include a Monitored Retrievable Storage (MRS) facility. The analyses were performed for the U.S. Department of Energy (DOE) to determine if some of the benefits proposed for the improved performance waste management system (one with an MRS facility) could also benefit the authorized system (one without an MRS facility). The study showed that most of the alternatives evaluated would reduce the radiation doses to the public and the workers. Of the alternatives evaluated, the primary means for reducing these radiation doses is to increase the capacity of the transportation casks.

INTRODUCTION

In the commercial high-level waste management system, potential changes are being considered that will augment the benefits of an integral MRS facility in a system with an MRS facility (1). DOE has recognized that alternative options could be implemented in the authorized waste management system (i.e., without an integral MRS facility) to potentially achieve some of the same beneficial effects of the integral MRS system. The review copy of the MRS Proposal to Congress (1) summarized the analyses of such options that were conducted to support the need and feasibility analysis of an MRS facility. This paper summarizes the analyses related to radiation doses resulting from changes in the waste management system. These analyses were performed for DOE by Pacific Northwest Laboratory (PNL) (2) in support of the MRS need and feasibility studies.

In this paper the analyses of aggregated radiological dose impacts of nine hypothetical operating alternatives are presented in a generic reference system without an MRS facility. Changes are considered in the transportation system or in the location where an activity is carried out. The spent fuel management system in this analysis consists of a) loading of 10-year old spent fuel at reactor pools in shipping casks; b) transportation of the spent fuel by a combination of truck and rail for an average distance of 3000 km to a repository; and c) unloading the spent fuel at the repository and preparing it for emplacement. The system is shown schematically in Fig. 1. The spent fuel receiving facility at the repository was assumed to be the same as the conceptual design of the MRS facility, which uses conventional hands-on operation.

Time/motion and worker dose analyses were performed for the activities involving loading of spent fuel at reactors, and unloading the spent fuel and preparing it for emplacement at a repository. Doses to the public from these activities were adapted from available information. Doses during transportation by rail and truck were estimated using results from the RADTRAN transportation risk analysis code. The doses resulting from each of the nine postulated changes to the waste management system were estimated. These results were individually compared with those estimated for the assumed reference system, which was based on current knowledge of facility and transportation concepts and operations.

OVERALL BASES

Analyses in this study were aimed at estimating realistic dose rates believed to be achievable through repetitive experience for a hypothetical waste management system. The results are useful for overall comparisons of system alternatives, but are not intended as absolute values for specific sites, routes and designs, or for specific affected public or workers.

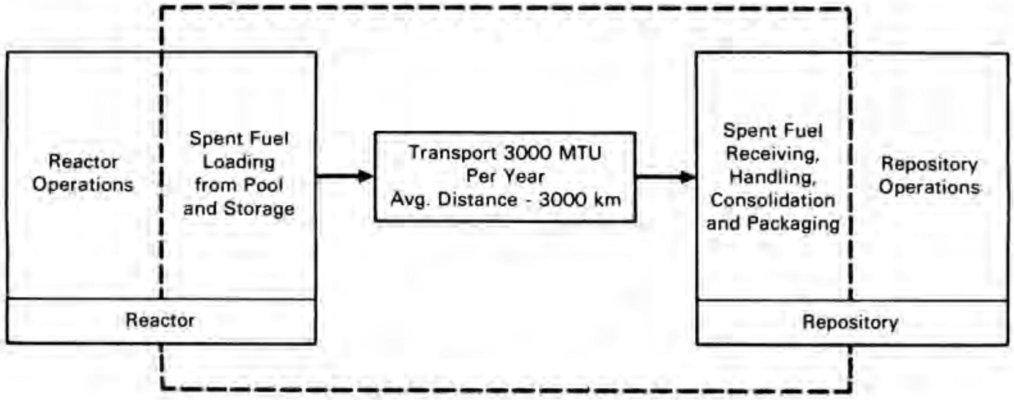

Fig. 1. Reference Study System.

The radiological doses examined in this study are those to the affected public and to the workers in the waste management system. The dose estimates include the radiological doses from routine activities and in some cases the expected doses (i.e., probabilities multiplied by consequences) from accidents. This study does not analyze the cost, feasibility, or other considerations of implementing the potential changes in the waste management system.

The reference waste management system used in this study is broadly defined below:

- No MRS facility is in the system.
- Loading of spent fuel into transportation casks and preparations for shipment are included in the overall system.
- Consolidation of spent fuel occurs at the repository; no spent-fuel consolidation or canisterization occurs at reactors.
- Reactors that can ship spent fuel to the repository by rail will do so; reactors without rail shipment capability will ship by truck.
- The repository is in the western part of the U.S.
- All spent fuel transported to the repository has been irradiated to 33,000 MWD/MT and is 10 years old since discharge from the reactor.

From this broad reference system definition, the following additional major bases and assumptions were applied to the analyses for the reference system.

- Generic, "typical" data are used throughout.
- Spent fuel is from pressurized water reactors (PWRs), and each assembly contains 0.462 MTU (based in initial fuel content).
- The radiation dose rates from loaded transportation casks are two- to four-fold below the regulatory maxima.
- Shipments from reactors are 30%/70% by general commerce truck/general freight rail, respectively, on the basis of weight of the fuel material.
- The reference truck cask has the capacity to carry two intact PWR fuel assemblies.
- The reference rail cask (loaded weight, approximately 100 tons) has the capacity to carry 14 intact PWR fuel assemblies.

OVERALL DOSES OF REFERENCE SYSTEM

The overall aggregated radiation doses for the hypothetical reference waste management system are given in Table I. Table I shows that the aggregated radiation doses would be low and about equally divided between the public and occupational workers for the reference system. The doses to the public would be dominated by those from transportation from truck shipments. The doses to the occupational workers would be highest at the reactor or repository, and about the same at each location. These doses would also be dominated by those from truck shipments.

These are the aggregated doses against which the calculated doses for potential system alternatives are compared in the next section.

DOSE COMPARISONS OF POTENTIAL SYSTEM ALTERNATIVES

In a waste management system without an MRS facility, the hypothetical changes that were identified and evaluated in this study are as follows:

1. All reactors that cannot ship by rail (i.e., rail-limited reactors with about 30% of the total spent fuel) are modified to ship by rail.
2. All truck shipments from rail-limited reactors are made in overweight trucks (with assumed capacity of four intact PWR assemblies.
3. Rail-limited reactors load into reference rail casks that are heavy-hauled by truck to the nearest practical rail head, transferred to a rail car, and transported by rail the remaining distance to the repository.

TABLE I

Radiation Doses in the Assumed Reference Spent Fuel Waste Management System

	Radiological Doses (person-mrem/MTU)					
	Truck Shipment		Rail Shipment		30%/70% by Truck/Rail	
	Public	Occupational	Public	Occupational	Public	Occupational
Spent-fuel handling at reactor[a]	<1	160	<1	40	<1	80
Transportation[b]	530	100[c]	6	5[c]	160	30[c]
Spent-fuel handling at surface facilities at repository[a,d]	6	140	8	30	6	60
	540	400	15	75	170	170

(a) Excludes accident risks.
(b) For 3000 km between reactor and repository.
(c) Transport workers.
(d) Includes spent-fuel consolidation at the repository.

4. Reactors with rail handling capability ship in extra-large, 150-ton rail casks (with assumed capacity of 36 intact PWR assemblies).

5. Rail shipments are marshaled at each reactor (that can ship only by rail), then shipped in five-car dedicated trains to the repository.

6. Rail shipments from reactors are sent to offsite marshaling points, where they are combined into five-car dedicated trains for transport to the repository.

7. Reactors consolidate spent fuel and place fuel rods in canisters before shipment. The resultant cask capacities are increased by a factor of two for spent fuel, or the casks contain nonfuel-bearing hardware that is compressed to 1/10 the volume of the original spent fuel.

8. All dry storage is at reactors and is in nontransportable rail-size casks (same capacity as the reference rail transport cask), and transfer to transportation casks is by dry transfer.

9. All dry storage is at reactors and is in transportable rail casks (with assumed capacity the same as the reference rail transportation casks).

The alternatives of different designs at the repository receiving and handling facility at the repository (e.g., utilizing remote-automated concepts) were not evaluated in this study, but are currently being assessed in other studies.

The aggregated radiation dose impacts of each alternative if applied individually to the reference waste management system was examined. Some of the hypothetical changes could be combined (e.g., at-reactor consolidation plus use of larger transportation casks), but the impacts of such combinations were not evaluated.

The results of the analyses are summarized in Table II. The estimates for the reference study system are given in the first two rows of values in Table II. The dose values for each alternative are to be compared individually with these reference system values. The approximate percent of the total spent fuel for the first repository is given in the first column of values in Table II. The approximate contribution of doses to the total system for each alternative can be obtained by multiplying the dose values in the table by this fractional contribution. Doses to the public generally would be affected only by changes in the in-transit component (except for at-reactor consolidation), whereas doses to the workers would be changed in all three components, but would generally be more affected at the reactor or at the repository.

CONCLUSIONS

The major conclusion from the study is that the primary means for reducing the radiation doses to the public and the workers in the system is to increase cask capacity (and reduce the number of shipments) if all other factors remain constant. Changes in specific facility and cask designs (e.g., using remotely operated concepts, using more shielding on casks, etc.) may also reduce radiation doses, but were not studied in this analysis.

Most of the alternatives considered would tend to reduce the unit radiation doses to the public and to workers because of the fewer transportation cask shipments. A notable exception to this is the increased worker doses at the reactor arising from the alternative of at-reactor consolidation of spent fuel.

Some overall conclusions reached from these analyses are as follows:

1. The largest contribution to unit radiological doses in the reference system in this study would be from transportation in legal-weight trucks. Therefore, the largest potential for dose reduction would result from using larger casks where possible rather than reference legal-weight trucks. Public doses would be affected the most by the use of this alternative, although worker doses also would be significantly affected. Public doses would be reduced because of the nearby public's exposure to the modest radiation levels from fewer shipments in larger-capacity casks. Worker doses would be reduced because the worker manpower per shipment would not change significantly with cask capacity, so fewer workers would be exposed during the fewer shipments with high-capacity casks. Using larger casks rather than reference legal-weight truck casks would decrease doses throughout the system.

2. Reducing the number of transportation cask loads (i.e., increasing the cask cargo capacity) of spent fuel would reduce the public and occupational doses in all cases. Reducing the number of cask loads would involve changing from legal-weight to over weight truck, from truck to rail, or from reference rail to large rail casks. Changing from truck to rail casks would yield the most significant change; changing from reference rail casks to large rail casks would yield a smaller dose reduction because the doses from using the reference rail cask already would be quite low.

3. Marshaling rail cars at the reactors and away from the reactors to form multicar dedicate trains would have only small effects on unit doses. The effects would be small, largely because the doses from using rail transport would be quite low without marshaling. Doses would increase only slightly at the marshaling location.

4. At-reactor consolidation of spent fuel would increase the radiation doses to the workers compared with at-repository consolidation. Reactor worker doses resulting from at-reactor consolidation would be greater than from at-repository consolidation because the repository would be designed to perform this function efficiently using heavily shielded hot cells, whereas the function would be an add-on capability in the reactor storage pool. However, at-reactor consolidation would reduce worker doses from transportation and from at-repository fuel receiving activities because of the resulting fewer number of shipments. Public radiation doses also would be reduced from at-reactor consolidation.

TABLE II

Estimated Radiation Doses for the Study Reference Waste Management System and Hypothetical Alternatives[a]

Alternative	Approximate Maximum Percent of Spent Fuel Affected	Unit Dose, person-mrem/MTU: Public At-Reactor	Public In-Transit[b]	Public At-Repository	Public Total	Workers At-Reactor	Workers In-Transit[b]	Workers At-Repository	Workers Total
Reference Study System: Truck	30	<1	530	6	540	160	100	140	400
Rail	70	<1	8	6	15	40	5	30	75
Hypothetical Alternatives									
1. All fuel is shipped by rail in 100-T casks.	30	<1	6	6	15	40	5	30	75
2. All trucks are overweight.	30	<1	380	6	390	75	75	75	230
3. Rail-sized casks are heavy-hauled[a] to rail head and transferred to rail.	30	<1	8	6	15	40	20	30	90
4. Extra large rail casks (150T) are used.	70[d]	<1	4	6	10	20	2	15	35
5. Rail shipments are marshaled at reactors and shipped by dedicated train.	70[d]	<1	5	6	10	40	<1	30	70
6. Rail shipments are marshaled offsite and shipped by dedicated train.[e]	70[d]	<1	7	6	15	40	1	30	70
7. Fuel is consolidated at reactor:									
Truck	30	6	290	<1	300	280	50	80	410
Rail	70	6	5	<1	10	190	3	20	210
8A. Reactors use dry storage with wet transfer.[d,f,g]	10	<1	8	6	15	110[h]	5	30[h]	140
8B. Reactors use dry storage with dry transfer.[d,f,g]	10	<1	8	6	15	70[h]	5	30[h]	105
9. Reactors use dry storage in transportable rail casks.[d,f]	10	<1	8	6	15	60[h]	5	30[h]	95

(a) Based on no-MRS in the system.
(b) Equivalent to 1 MTU shipped an average of 3000 km.
(c) Heavy-haul distance is assumed to be 20 km.
(d) Assumes applicability to all reactors with rail capability.
(e) Assumes 100 km to marshaling yard.
(f) Assumes shipment by rail.
(g) The reference case assumes wet transfer from dry storage at reactors.
(h) These values should be compared with those in the reference case with no interim storage at the reactor, and with dry storage at the repository of 50 mrem/MTU, for a total system worker dose of 95 mrem/MTU.

5. Extended interim dry storage of spent fuel at the reactors would increase somewhat the combined worker doses at the reactor and repository compared to interim storage at the repository, if wet transfer back to the transportation cask were used. If dry transfer were used, the combined worker doses would be affected very little.

6. Dry transfer of spent fuel at reactors from dry storage casks to transportation casks would slightly reduce the worker doses compared with the conventional wet transfer because dry transfer would required fewer handling operations than wet transfer.

7. Using transportable dry storage casks at the reactors would result in essentially no change in worker doses, compared to having extended interim dry storage at the repository. This assumes the casks are recertifiable for transportation without unloading prior to transport.

REFERENCES

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