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IMPACT OF MORE CONSERVATIVE CASK DESIGNS ON THE CRWMS TRANSPORTATION SYSTEM

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ABSTRACT

The Office of Civilian Radioactive Waste Management has been working since the mid-1980s to develop a cask fleet, which will include legal weight truck and rail/barge casks, for the transport of spent nuclear fuel (SNF) from reactors to Civilian Radioactive Waste Management System SNF receiving sites. The cask designs resulting from this effort have been identified as Initiative I casks. In order to maximize payloads, advanced technologies have been incorporated in the Initiative I cask designs, and some design margins have been reduced. Due to the wide range of the characteristics (age/burnup) of the spent fuel assemblies to be transported in the Initiative I casks, it has become apparent that a significant portion of the shipments of the Initiative I casks could not be loaded to their design capacity. Application of a more conventional cask design philosophy might result in new generation casks that would be easier to license, have more operational flexibility as to the range of age/burnup fuel that could be transported at full load, and be easier to fabricate. In general, these casks would have a lower capacity than the currently proposed Initiative I casks, thereby increasing the transportation impacts and the transportation costs.

I. INTRODUCTION

The Office of Civilian Radioactive Waste Management (OCRWM) has been working since the mid-1980s to develop a cask fleet, which will include legal weight truck (LWT) and rail/barge casks, for the transport of spent nuclear fuel (SNF) from reactors to Civilian Radioactive Waste Management System (CRWMS) SNF receiving sites. The cask designs resulting from this effort have been identified as Initiative I casks.

Because the design efforts for the Initiative I casks have focused on maximizing payloads in term of numbers of assemblies, some advanced technology concepts (such as burnup credit) have been included in the designs, and some design margins have been reduced to a minimum. Various alternatives to using the advanced technologies and/or the reduction of design margins have been recommended by some experts. However, applying these alternative approaches would generally result in a reduced payload, because the alternative design concepts usually include smaller-diameter cask bodies, different materials of construction, different lid designs and lid-sealing systems, smaller-diameter baskets, and reduced weights for the loaded casks, etc.

Due to the wide range of characteristics (age/burnup) of the spent fuel assemblies expected to be transported in the CRWMS transportation system, it may be necessary to operate the Cask System Development Project (CSDP) Initiative I casks, as currently conceived, either with: fewer assemblies in the baskets ("empty-hole" derating, which is discussed from a radiological standpoint in ref. 1) or with specially designed reduced-capacity baskets.[2]

Since a number of more conservative cask designs with somewhat smaller capacities than the Initiative I casks have been suggested for use in the CRWMS, it is useful to define both the operational and cost impacts of using such reduced-capacity casks. As a basis for comparison, the operational parameters and costs of operating these reduced-capacity casks will be compared with those projected for the currently proposed Initiative I casks.

II. CASK DESIGNS

The capacities of the CSDP Initiative I cask designs, along with the capacities for a number of possible more conservative cask designs, are summarized in Table 1.

The Initiative I cask concept includes a large rail/barge cask (the BR-100) and two LWT cask designs (the GA-4 and the GA-9). The BR-100 rail/barge cask will be capable of transporting 21 pressurized water reactor (PWR) or 52 boiling water reactor (BWR) assemblies. A removable basket is used to transport the different assemblies in the same cask body. The GA-4 cask is an LWT cask designed specifically for the transport of PWR fuel assemblies while the GA-9 cask is designed for the transport of BWR assemblies. The capacities of the Initiative I truck casks are four and nine assemblies respectively.

A modified BR-100 rail/barge cask, which would be able to transport 16 PWR or 37 BWR assemblies, has been receiving some consideration. Due to its smaller size, this cask would provide for more operational flexibility at the reactors. The modified BR-100 cask is expected to be a lighter cask (a hook weight less than 100 tons when the cavity is filled with water), which potentially would permit rail shipments at reactors that would not be able to handle the currently designed Initiative I rail/barge cask. With its smaller payload, a modified BR-100 cask might be expected to be able to transport younger and hotter fuel than the current Initiative I rail/barge cask design. As a result, relatively little cask derating would be expected for the modified BR-100 rail/barge cask.

Table 1. Cask design capacities

Cask	Capacity, assemblies			
	Rail/barge		Legal weight truck	
	PWR	BWR	PWR	BWR
Initiative I	21	52	4	9
Modified BR-100	16	37	--	--
Modified GA-9	--	--	--	4
New Initiative	12	24	2	5
Current Design	7	18	1	2

A modified GA-9 truck cask has also been included in a number of more conservative cask design studies. The modified GA-9 cask is a variation of the original GA-9 design, where a special large-opening internal basket would be installed, thus permitting the loading of channelized BWR fuel assemblies. The capacity of the modified GA-9 cask is assumed to be that of four BWR assemblies.

A New Initiative cask concept, shown in Table I, might include a rail barge cask capable of transporting 12 PWR or 24 BWR assemblies and 2 truck casks which are assumed to have capacities of 2 PWR and 5 BWR assemblies respectively. It is assumed that the New Initiative casks would be designed by using standard technologies which have already been approved by the Nuclear Regulatory Commission (NRC). For example, fuel burnup credit would not be included in the design of the fuel baskets. It is projected that the designs for the New Initiative casks would be based on 7-year-old fuel and a burnup of 45,000 MWd/MTU. Considering the anticipated range of characteristics for the fuel assemblies expected to be transported in the CRWMS, it should be possible to consistently load the New Initiative casks to their full capacity (i.e., essentially no cask derating). Due to the use of standard cask design concepts, it is anticipated that the New Initiative casks could be licensed for transport in a minimum amount of time, which in turn might permit the construction of a fleet of New Initiative casks prior to the start of CRWMS operation in 1998.

The U.S. Department of Energy also has the option of using a cask fleet based on current cask designs. The current cask designs, shown in Table 1, are based on the Nuclear Assurance Corporation (NAC) LWT cask and the IF-300 rail cask, which are currently being used to transport SNF. These casks have relatively small capacities (1 PWR or 2 BWR assemblies for the NAC LWT cask and 7 PWR or 18 BWR assemblies for the IF-300 rail cask). Since these casks are currently licensed for transport or have been licensed by the NRC in the past, licensing new casks constructed to these designs is possible. The IF-300 cask was designed to transport short-cooled fuel (approximately 180 days), and considering the age/burnup combinations of the SNF expected to be transported in the CRWMS, it is extremely unlikely that any of the rail shipment would have to be derated. The design specifications of the NAC LWT cask are based on 2-year-old assemblies and a burnup of 35,000 MWd/MTU. Even for this design, it is unlikely that cask derating would be a factor in CRWMS operation.

Operational impacts have been assessed for a number of fleets utilizing the casks shown in Table 1. The cask fleets considered in the individual scenarios are described in Section III. The operational impacts, discussed in Section IV, are summarized in terms of number of visits to sites (both shipping and receiving) and the cask fleet size, which would equate to the number of visits to a cask maintenance facility. The cost impacts which include operational costs, cask purchase and decommissioning costs, and cask maintenance costs associated with the use of these casks have also been assessed and are presented in Section III.

III. TRANSPORTATION SCENARIOS

The operational impacts and transportation system costs of using fleets of different-capacity casks have been estimated for a number of transportation scenarios. All of these scenarios are based on the movement of 62,200 MTU of spent fuel from reactor storage pools to a generic eastern monitored retrievable storage (MRS) facility. The lower bounding case[3] was used to define the acceptance rate for this study. Standard transportation assumptions were used to predict the number of cask loads, transport costs, and cask fleet size. These assumptions are summarized in ref. 2.

The oldest-fuel-first allocation assumption was used to estimate the number of assemblies to be shipped annually from each reactor storage pool. In addition, it was also assumed that there would be no intrautility or interutility distribution of delivery rights. Two cask-handling cases are included in this study: (1) a low rail case (where it was assumed that only 26% of the SNF would be transported in rail casks) and (2) a high rail case (where it was assumed that approximately 63% of the SNF would be transported in rail casks). The first case, the low rail case, is based on an assumption that only 22 sites would be able to accommodate Initiative I rail casks. Due to the heavy dependence on truck transport, this case was included to place an upper bound on the transportation impacts associated with the more conservative cask designs. The basis for the high rail case assumes that the cask-receiving facilities at a number of reactor sites could be modified so that an additional 36 sites would be able to handling the larger rail/barge casks (i.e., it was assumed that a total of 58 sites would make SNF shipments in rail casks).

A series of five scenarios has been defined for each cask handling case. The first, which forms the base case for the comparisons discussed in this paper, is based on the assumption that the Initiative I casks would be used to perform all transportation activities. The Initiative I scenarios are reported as scenarios 1 and 6 in Table 2.

Two of the reduced-cask-capacity scenarios use a combination of Initiative I casks and modified Initiative I casks. The first reduced-capacity concept (scenarios 2 and 7 in Table 2) is based on the following assumptions: (1) all rail shipments would be made using the modified BR-100 cask and (2) all truck shipments will be made using the Initiative I truck casks (the GA-4 and the GA-9 casks). The cask fleet assumptions for scenarios 3 and 8 are similar to those used in scenarios 2 and 7 with the exception that the modified GA-9 cask is assumed to be used to transport BWR assemblies.

Scenarios 4 and 9 are based on the use of the New Initiative cask concept. The final scenarios, scenarios 5 and 10, for each case are included to place an upper limit on the CRWMS transportation impacts. These scenarios are based on using current design casks to perform all transportation activities.

IV. RESULTS

The impacts of using Initiative I or other combinations of more conservative cask designs to transport spent fuel assemblies in the CRWMS transportation system are summarized in this section. The discussion centers on a number of issues including number of cask loads, cask fleet size, operational activity at various CRWMS facilities, cost, and transportation risk.

A. Transportation Impacts

A summary of the transportation impacts of using the different cask designs is presented in Table 2. The Initiative I cask fleet is used as the base case for this study.

1. Low rail case. The number of cask loads required to transport a specific quantity of fuel assemblies is directly proportional to the cask capacity. When the large-capacity Initiative I casks are used, 29,520 cask loads (1754 rail and 27,766 truck) are required to transport 62,200 MTU of SNF. The operational impacts of using reduced-capacity baskets to satisfy loading site fuel delivery requirements are not addressed here. The effects of using cask derating to fulfill these needs are discussed in Part B of Section IV.

The smaller-capacity rail cask used in scenario 2 resulted in a 33% increase in the number of rail cask loads (2341 as compared with the 1754 rail cask loads needed with the Initiative I rail barge cask). In scenario 3, the Initiative I GA-9 BWR truck cask was replaced with the modified GA-9 cask; this had a major impact on the number of cask loads needed to transport the BWR assemblies. The total number of truck cask loads in scenario 3 is 49% higher than the value reported for the base case. Using the Initiative I truck cask results in 10,998 BWR cask loads and 16,778 PWR cask loads. When the modified GA-9 cask is included in the cask fleet, the number of BWR cask loads increases to 24,699. Since the GA-4 cask is used to transport PWR assemblies in both scenarios, the number of PWR truck cask loads is the same.

Use of the New Initiative casks would result in a further increase in the number of cask loads. A total of 56,535 cask loads (3252 rail and 53,283 truck) is projected when the New Initiative casks are used, a 91% increase over the base case. A major portion of this increase is associated with the PWR truck shipments as a result of the 50% reduction in the PWR truck cask capacity. Because the New Initiative BWR truck cask has a larger capacity than the modified GA-9 cask used in scenario 3, the number of BWR truck shipments in scenario 4 is somewhat lower than that reported for scenario 3. The final scenario included in the low rail case represents the use of current design cask to perform all of the transportation activities. With these casks, approximately 121,600 cask loads would be required to transport the 62,200 MTU of SNF. Due to the small capacities of the truck casks (one PWR or two BWR assemblies), over 95% of the cask loads are associated with truck shipments.

The size of the cask fleet is also a function of the cask capacity. It is projected that a total of 57 Initiative I casks would be needed for the base case, scenario 1. A cask fleet of almost 200 casks would be needed if all of the transportation activities involved current design casks, scenario 5. This fleet is almost 3.5 times that required for the base case.

The estimated transportation costs reported in Table 2 include operational costs, cask acquisition and decommissioning costs, and cask maintenance costs. The estimated transportation costs vary from $668 million for the Initiative I casks to $2536 million for the current cask designs.

2. High rail case. In the high rail case, approximately 63% of the fuel is assumed to be transported in rail/barge casks. While this results in a higher number of rail cask loads, increased use of the higher-capacity rail/barge casks significantly reduces the number of truck cask loads. For example, the Initiative I high rail case, scenario 6, has 2502 more rail cask loads than the corresponding scenario for the low rail case, scenario 1. However, the number of truck cask loads has been significantly reduced, 14,119 in scenario 6 as compared with 27,766 for scenario 1. In other words, each rail cask load replaces 5.45 truck cask loads. For the current design casks, comparing scenarios 5 and 10 shows that each rail cask load would replace 7.8 truck cask loads.

The projected cask fleets for the high rail case are somewhat lower than the corresponding cask fleets for the low rail case (from a reduction of 1 cask for the Initiative I casks to 38 casks for the current design casks). The relative insensitivity of the cask fleet size is due to the slower average transport speed and longer loading/unloading times associated with the rail/barge casks. In essence, on an annual basis, the relatively large capacity Initiative I truck casks are expected to transport approximately the same amount of fuel as the rail casks.[4] However, for the current cask design scenarios, the IF-300 casks are projected to transport approximately three times as much fuel annually as the NAC LWT casks. Due to the larger rail-truck capacity ratio for the current design casks, increasing the proportion of the fuel transported by rail/barge casks results in a smaller cask fleet.

As shown in Table 2, rail transport of SNF assemblies is more cost-effective than truck transport. The estimated transportation costs for the high rail case are 15 to 25% lower than the corresponding scenarios included in the low rail case.

Table 2. Summary of transportation impacts of using reduced-capacity casks

Scenario			Cask loads		Cask fleet size			Transportation costs, $ x 10⁶
Number	Casks	Handling capability	Rail	Truck	Rail	Truck	Total	
1	Initiative I rail/barge and truck casks	Low Rail	1,754	27,766	16	41	57	667.9
2	Modified BR-100 and Initiative I truck casks	Low Rail	2,341	27,766	18	41	59	695.2
3	Modified BR-100, Modified GA-9, and GA-4	Low Rail	2,341	41,477	18	62	80	949.4
4	New Initiative casks	Low Rail	3,252	53,283	24	78	102	1,244.8
5	Current Cask Design	Low Rail	5,191	116,399	37	160	197	2,536.1
6	Initiative I	High Rail	4,256	14,119	33	23	56	570.0
7	Modified BR-100 and Initiative I truck casks	High Rail	5,723	14,119	39	23	52	640.0
8	Modified BR-100, Modified GA-9, and GA-4-2	High Rail	5,723	19,895	39	32	71	755.8
9	New Initiative casks	High Rail	8,080	27,282	53	41	94	1,032.2
10	Current Design	High Rail	12,541	58,702	78	81	159	1,896.1

B. Cask Derating

The data presented in Table 2 are based on the assumption that all of the casks would be loaded to full capacity. As stated above, the varying spent fuel assembly characteristics (age/burnup) will probably result in the need to derate a number of the Initiative I cask shipments. Hence, the actual number of cask loads may exceed the values reported in Table 2.

A study of derating Initiative I cask using specially designed smaller-capacity baskets is presented in ref. 2. That study showed that, if the oldest fuel was transported from the reactor storage pools, a significant portion of the assemblies would have to be transported at less than full cask capacity. Assuming the same percentages apply to this study, cask derating in the low rail case would increase the number of cask loads for scenario 1 from the 29,520 reported in Table 2 to 36,340. The corresponding value for the high rail case, scenario 6, is 22,600 cask loads rather than the 18,375 cask loads reported in Table 2.

Without any design information, it is difficult to estimate the amount of derating that would occur with the reduced capacity casks. It is estimated that the use of the modified BR-100 rail/barge cask in scenarios 2 and 7 would only have only a minor impact on the number of cask loads. While little if any derating would be expected for the rail/barge cask, the continued need to derate the Initiative I truck shipments would still result in an approximately 25% increase in the number of cask loads.

Since the New Initiative cask designs are expected to be based on 7-year-old fuel and a 45,000 MWd/MTU burnup, the number of derated shipments is expected to be significantly reduced. Even if the youngest eligible fuel is selected from the reactor fuel storage pools, the average age of the fuel being transported in 1998 is 8.6 years. As the scenario progresses, the average fuel age is projected to slowly increase to 15 years by 2021. Hence, only a very small portion of the fuel assemblies eligible to be accepted by the CRWMS would have to be transported in derated cask shipments.

Considering the more stringent design specification for the current cask designs, it is unlikely that there would be any derated cask shipments. While the reduced capacities of the more conservative cask designs result in a increased number of cask loads, the ability to load a higher proportion of the cask loads to full capacity has a mitigating influence. For example, when comparing scenarios 1 and 5, the use of the current cask design in the low rail case requires 312% more cask loads than the use of the Initiative I casks. However, if cask derating is taken into account, the relative increase associated with the use of current design casks is only 235%. The corresponding increases in the number of cask loads for the New Initiative casks are decreased from the approximately 90% shown in Table 2 to only 55% when cask derating is included in the analysis.

C. Impact on CRWMS Facilities

The current CRWMS operational concept includes an MRS facility that would provide temporary storage for a quantity of spent fuel between the start of operation in 1998 and the opening of the repository. The casks transporting the spent fuel assemblies from the reactor will be unloaded at the MRS, with the assemblies being placed in a suitable storage container. After the repository has reached its design operating level, the MRS operation may change. Rather than unloading all casks that arrive at the MRS, the loaded rail/barge casks could be shipped directly to the repository for processing. However, it is projected that the truck casks will still be unloaded and the spent fuel assemblies will be placed in an MRS repository cask for shipment to the repository.

The major MRS operational activity is the unloading and processing of transportation casks. The number of casks that have to be unloaded annually is one of the key MRS design specifications. This parameter determines the number of cask-handling lines that must be included in the MRS design.

The MRS conceptual design currently includes three processing cells, with each cell containing two cask-handling lines and unloading ports. This design was based on the use of the Initiative I transport casks. The use of lower-capacity casks results in an increased number of cask loads that must be processed. This is particularly true for the truck transport segment of the CRWMS transportation system. Operational simulations of the MRS[7] have shown that the cask-handling facilities are the limiting factor in determining throughput capacity. As the number of cask loads increases, the utilization of the MRS will increase until it reaches its limit.

More recent MRS operational simulations have indicated that the conceptual MRS design would not be able to process a sufficient number of the New Initiative casks to maintain a 3000-MTU/year throughput. In order to increase the throughput, it would be necessary to increase the working hours (work 7 days/week rather than 5 days/week) or to increase the number of processing cells. These solutions would either increase the cost of the MRS or require additional personnel to staff the facility.

A Cask Maintenance Facility (CMF) has been included in many CRWMS designs to provide a facility to maintain and service the transportation casks. The casks will need to be maintained at least annually, and many experts have indicated that it may be necessary to send a cask to the CMF a number of times each year for cleaning or other nonroutine maintenance service. Using a lower-capacity cask for the transport implies that a larger cask fleet must be purchased, operated, and maintained, which translates into an increased load on the CMF. The size and the number of processing stations at the CMF are a function of the number of cask visits anticipated annually. Hence, like the MRS the CMF must increase in size as the cask capacity decreases. Again, increasing facility size and staff increases the capital and operating costs of the CMF.

Since the repository is not scheduled to start operation until at least 2010, very little conceptual design information is available at this time. However, drawing an analogy with the MRS, an increase in the number of casks that must be processed at the repository will increase the size and hence the cost of the repository surface facilities.

The size and number of cask-loading facilities at the reactor sites are fixed. These facilities have already been constructed. The cost of loading transport casks at the reactor sites is directly proportional to the number of casks loads needed to transport the fuel assemblies. Again, with the smaller-capacity casks, the loading facilities will have to load more casks, with a resulting increase in the manpower requirements.

Basically, reduced cask capacities will tend to increase the cost of constructing and operating the various CRWMS facilities.

D. Risk Considerations

The risk associated with the transport of SNF is an important consideration. In general, the risk associated with normal transportation is proportional to the number of cask loads used to transport the fuel assemblies to an MRS or a repository. One of the major components of risk in normal transport is the radiation exposure to the general public. Without detailed design information, it is difficult to estimate the radiation levels emanating from the more conservative cask designs. As a first (and bounding) approximation, if it is assumed that all of the casks will be loaded to the 10-mrem/h regulatory limit,[a] the public radiation exposure is truly proportional to the cask capacity. However, it is anticipated that with the more robust designs, the actual loading of the smaller-capacity casks might result in lower external radiation levels. Hence, while reduced-cask capacity may result in an increased public radiation exposure, the increase would probably be less than values directly proportional to the cask capacity.

Other risk factors, such as injuries and fatalities due to traffic accidents involving spent fuel casks, are proportional to the number of cask miles traveled which in turn is directly proportional to the cask capacity.

V. CONCLUSIONS

In order to maximize payloads in the Initiative I cask designs, advanced technologies have been incorporated, and some design margins have been reduced. Due to the wide range of the characteristics (age/burnup) of the spent fuel assemblies to be transported in the Initiative I casks, it has become apparent that a significant portion of the shipments the Initiative I casks could not be loaded to their design capacity. Use of more conventional cask design philosophy might result in new generation casks that are easier to license, have more operational flexibility as to the range of age/burnup fuel that could be transported at full load, and are easier to fabricate. In general, these casks would have a lower capacity than the currently proposed Initiative I casks, thereby increasing the transportation impacts and the transportation costs.

A comparison of the transportation impacts associated with the different cask designs indicates that the New Initiative cask concept would result in a 91% increase in the number of cask loads for the low rail case. Use of the even more conservative current cask designs would result in a 312% increase in the number of cask loads. Corresponding increases in the cask fleet size and transportation costs are projected.

Enhancing the at-reactor cask-handling capabilities to maximize the use of rail shipments reduces transportation impact of the different cask design concepts (i.e., less cask loads, smaller cask fleets, and reduced transportation costs). However, the relative impact of the various scenarios is essentially the same in both the low and high rail cases.

Considering the range of anticipated spent fuel characteristics, it is apparent that approximately 23% of the assemblies being transported in the Initiative I casks will need to be transported at less than full capacity (i.e., derated shipments). While it is conceivable that some cask derating could be expected with the New Initiative cask concept considered, the relative impact of derating is expected to be significantly smaller. Little or no cask derating is anticipated for use of the current cask designs.

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