PUBLIC SUMMARY

The use of nuclear (radioactive) materials have great potential benefits to the US public; however because of the tremendous energy produced from the fissioning of nuclear materials, such as in nuclear [power plants, there is an associated risk with the use of these materials. Spent nuclear fuel is extremely radioactive. People are understandably concerned when spent fuel is moved in trucks and by rail over public roads and railroads. Thirty-five years ago the Nuclear Regulatory Commission responded to this concern by estimating what the radiation impact of transporting radioactive materials, including spent fuel, would be. The result was the Final Environmental Statement (EIS) on the Transportation of Radioactive Material by Air and Other Modes, NUREG-0170, published in 1977 (NRC, 1977). This EIS included transportation of all types of radioactive material by road, rail, air, and water and concluded that:

- The average radiation dose to members of the public from routine transportation of radioactive materials is a fraction of the background dose.
- The radiological risk from accidents in transporting radioactive materials is very small compared to the non-radiological risk from accidents involving large trucks or freight trains.

On the basis of this EIS, 1981 regulations were considered "adequate to protect the public against unreasonable risk from the transport of radioactive materials." The adequacy of these regulations was questioned, however, because the EIS was based mostly on estimates of radiation dose and accident rate, and not much data or information was available to support those estimates. Questions about "reasonable" risk and accident consequences ("what if the accident does happen?") were also raised. To this end the question arises, what constitutes an acceptable risk to the public? As straightforward as it appears, there is no single answer to this question. What we accept as a risk for many daily activities is far greater than what we accept or perceive as our risk from other activities. For example, the fear and associated risks of daily activities around the house, or driving to and from work are perceived to be small and readily accepted while the fear and acceptance of risk by many people associated with such things as plane travel or swimming in the ocean for fear of shark attack take on a perceived level of risk that is not consistent with actual quantitative risk. The challenge for a risk assessment such as this is to quantify the risk such that oversight organizations and the public they serve can make reasoned assessments as to the risk/benefit of these activities. To this end, the analysis presented in this document provide one portion of this assessment. The analyses that preceded this effort (i.e., NUREG-0170 and NUREG/CR-6672) have been updated herein to reflect more advanced models and methods. It is intended to determine whether more sophisticated models and methods will confirm and extend the level of assurance provided in these previous efforts. It is important to emphasize that this effort does not form the sole basis for the acceptance of risk associate with spent fuel shipments. Additional, specific analysis and/or testing for individual approval of all shipping casks, fuel shipments and proposed routes are all individually required. The purpose of this document in the overall assessment of spent fuel shipment risks is a global view of the societal risks, not individual approvals of specific casks, shipments, or routes.

Trucks and railcars carrying casks of spent nuclear fuel are subject to accidents like any other truck or railcar of similar size and weight. The Nuclear Regulatory Commission recognizes this, and requires that spent fuel casks be designed and built to withstand very severe accidents.

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Comment [h1]: EDITORIAL:Added this.

Comment [csb2]: This is still unclear. I am suggesting alternate wording.

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Comment [csb3]: This seems to imply that testing is required.

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Comment [csb5]: This is true, however, route controls and security escorts tend to reduce the likelihood of an accident during one of these shipments. The statement as it is could be misleading. These materials are not shipped like, say, gasoline is on the road, or chlorine is by rail.

Nonetheless, questions have been raised about accidents that are worse than those that the casks are designed for. The NUREG 0170 and later studies of casks have considered accident conditions more severe than the regulations require for cask certification.

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A 1987 study applied actual accident statistics to projected spent fuel transportation (Fisher, et al., 1987). This "Modal Study" also recognized that accidents could be described in terms of the strains they produced in the cask (for impacts) and the increase in cask temperature (for fires). Like NUREG-0170, the 1987 study based risk estimates on models because the limited number of accidents that had occurred involving spent fuel shipments were not sufficient to support projections or predictions. However, the Modal Study's refinement of modeling techniques and use of accident frequency data resulted in smaller assessed risks than had been projected by NUREG 0170.

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A 2000 study of two generic truck casks and two generic rail casks analyzed the cask structures and response to accidents using a computer modeling technique (Sprung, et al., 2000). Semi-detached trailer truck and rail accident statistics for general freight shipments were used because even by 2000 there had been too few accidents involving fuel cycle shipments to provide statistically valid data.

The dispersion of material released from the cask in an accident was also modeled with increasing refinement. NUREG-0170 assumed that most very severe accidents would result in release of all of the releasable cask contents to the environment; this engineering judgment overstated the release but was nevertheless used because analytical capabilities at the time did not permit a more accurate assessment of the release. The 2000 study analyzed the physical properties of spent fuel rods in a severe accident, and revised estimates of radioactive material that could be released to one percent or less of the NUREG-0170 estimates. Accordingly, risk estimates were revised downward. The 2000 study also verified that an accidental release of radioactive material could only be through the seals at the end of the cask where the lid is attached. In other words, a severe accident (more severe than those required to be evaluated in the regulations for radioactive material transportation) could cause only a seal failure, with no breach in the cask body.

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The present study models real casks and the commercial spent nuclear fuel that these casks are certified to transport. Two rail casks and a truck cask are evaluated. Rail casks are believed likely to be used for most future shipments.

Comment [csb6]: Can you qualify this statement? What is it based on?

Almost all spent fuel casks are shipped without incident. However, even this routine, incident free transportation causes radiation exposures because all loaded spent fuel casks emit some external radiation. The radiation dose rates for spent fuel shipments are measured before each shipment and required to be within regulatory limits. The radiation dose from this external radiation to any member of the public during routine transportation, including stops, is barely discernible compared to natural background radiation. Figure PS-1 shows an example cask and

Comment [csb7]: Upon what is this statement based? Do we have a record of the number of shipments? Do we recorded incidents for shipments of spent fuel? Does this statement cover both road and rail? The "Almost all" will bring questions from the public.

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Comment [csb8]: First time this term is used. I would look to introduce this. This could be handled in a "terms" section as part of this summary. If it is going to be "public friendly" I would highly recommend the use of a terms or definitions section.

the way the radiation to a member of the public is modeled.

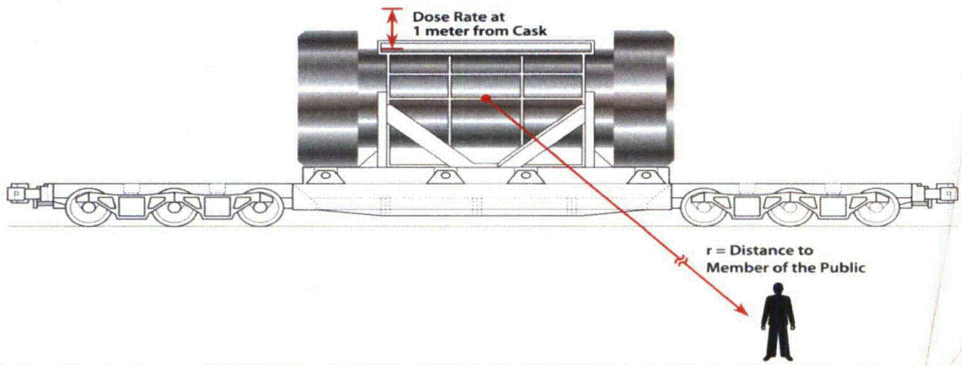

Figure PS-1. Model of a spent fuel cask in routine, incident-free transportation and radiation dose to a member of the public. Relative sizes of the cask and person are approximately to scale.

The external radiation from the spent fuel cask results in a very small dose to each member of the public along the route traveled by the cask. The collective dose from routine transportation is the sum of all of these doses. For this study, several example transportation routes were examined. Figure PS-2 shows the total dose to all of the exposed workers and members of the public for one of these routes, the truck shipment from the Maine Yankee Nuclear Power Plant to Oak Ridge National Laboratory. The background radiation dose to exposed workers and members of the public during the time of the shipment is included in Figure PS-2.

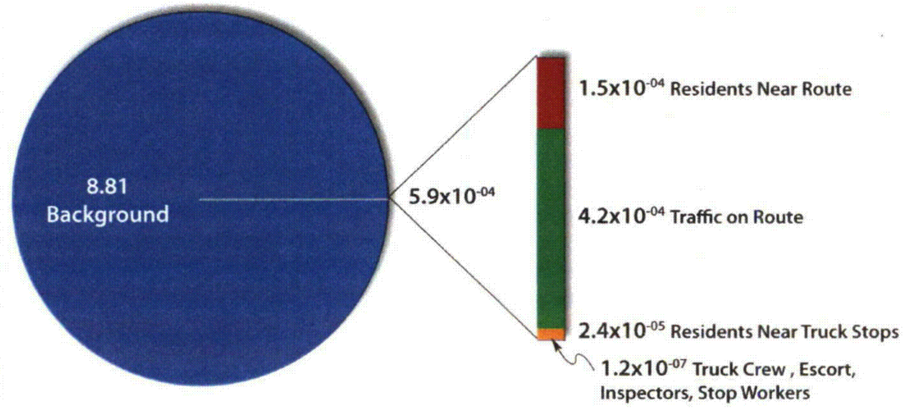

Figure PS-2. Collective Doses from Background and from a Truck Shipment of Spent Nuclear Fuel (Person-Sv)

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Comment [s9]: Figure PS-1: The portion of the figure schematically showing the "Dose at 1 meter from Cask" seems totally irrelevant since the Public Summary does not discuss the significance of this distance nor how the dose at this distance is used. (CParks)

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Comment [csb10]: You state that shipments will be mostly by rail and the diagram PS-1 is of a rail scenario, and yet you present results from a "truck" scenario. Would recommend trying to be consistent.

Comment [csb11]: There really is no context for this diagram. Would recommend putting units in this diagram, and providing a few text boxes (on the figure) that explain what it means.

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Comment [s12]: It is important to define the term person-SV early in the document. This is the first time it is used in the document and it is not defined until Section 2.3.2.on p. 18.

Comment [s13]: It would be useful to include somewhere in the description of the collective doses presented in Fig PS-2 the number of people considered for each component of the collective dose (i.e. how many "Residents Near Route, or "Traffic on Route," etc. are assumed).

Comment [s14]: 1.The figure captions need to be informative about the information in the plot, e.g. the figure caption for PS-2 indicates this is for a truck shipment, the text indicates this is for a truck shipment from Maine Yankee Nuclear Power Plant to Oak Ridge National Laboratory - this detail is important.

Comment [s15]: The collective dose value of 5.9E-4 is given in both figures PS-2 and PS-3, the first says this is a "truck shipment" which from the text is the Maine Yankee to Oak Ridge route and the latter "routine truck transportation" which is an average over 16 routes according to the text. Are these the same transportation scenarios? It is not clear from the figure captions.

The collective doses calculated for routine transportation are approximately the same for the 2000 study and for this study of the risks from spent fuel transportation, and are about 40 percent of the doses reported in NUREG-0170. Figure PS-3 shows a comparison of the collective doses from truck transportation, averaged over the sixteen routes studied.

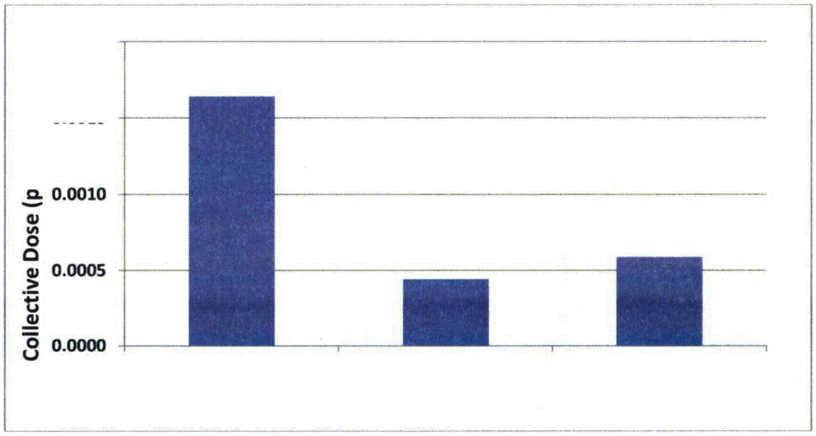

Figure PS-3. Collective doses (person-Sv) from routine truck transportation.

This study uses current (2006 to 2008) truck and rail accident statistics to determine the probability of an accident and the severity of that accident. Detailed analyses are performed to evaluate how the cask would respond to the accident scenarios. Figure PS-4 shows one impact scenario, a 97 kph (60 mph) corner impact onto a rigid target, and the resulting deformations. Almost all of the deformation is in the impact limiter, a device that secured to the cask to absorb energy, much like the bumper of a car. Similar analyses were performed for impacts at 48, 97,145, and 193 kilometers per hour (kph)—equal to 30, 60, 90, and 120 mph—in end-on, corner, and side-on orientations for two cask designs. These impact speeds encompass all accidents for truck and rail transportation. Figure PS-5 shows one fire scenario, a three-hour engulfing fire, and the resulting temperature distribution in the cask. Additional simulations were performed with the fire offset from the cask. These fires encompass all fire-related accidents in rail transportation. The longest duration for an engulfing fire during truck transportation is one hour, due to the smaller amount of fuel that is carried on board a tanker truck.

The detailed simulations were performed for two spent fuel casks that are intended for transportation by railroad, the NAC-STC and the HI-STAR 100, and one truck transportation cask, the GA-4.

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Comment [h16]: How do the 16 routes chosen represent a bounding or representative set of potential doses? Most polls indicate that the public is generally in favor of nuclear power (which I suspect extends to nuclear fuel shipment) so long as it's not done "in my backyard". Given this general attitude and the fact that criticisms are continuously levied about the number and nature of the increased spent fuel shipments (and routes), some discussion of how these were selected and how they represent at least a similar set of routes (for comparison purposes) as previously considered or a representative sample would be useful in this summary. This would help ensure the charge that a judicious set of routes were chosen to ensure the doses/risks were favorable could not be levied.

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Comment [s17]: Border missing from bottom of chart. There needs to be a hyphen between NUREG and 0170 to be consistent with rest of report.

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Comment [csb18]: Consider that these limiters are "required" to meet the regulatory standards for packages. A footnote may be in order here.

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Comment [csb19]: On what is this based? This is a subjective comment that may be taken out of context and will be certainly be challenged. Recommend removal. Let members of the public come to this conclusion.

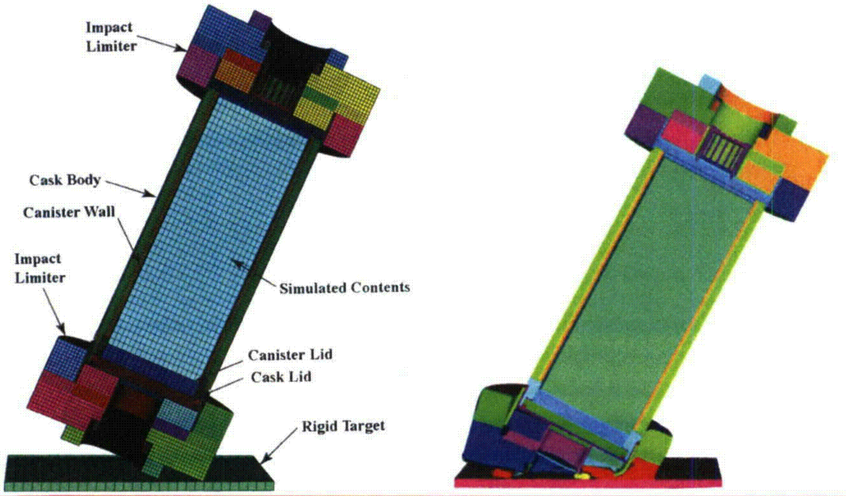
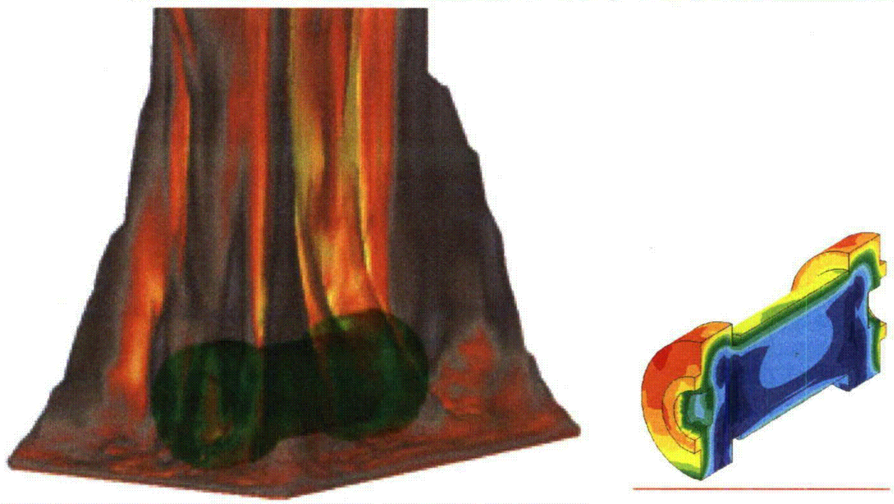


Figure PS-4. Corner impact onto a rigid target at 97 kph (60 mph) accident scenario for a spent fuel cask and the deformations produced by the impact.

Comment [MF20]: Note: on some printers, this figure does not print. Other printers it seems fine.



a) During fire b) After fire

Figure PS-5. Engulfing fire scenario and the temperature contours in the rail cask model following a 3-hour fire duration. The transparency of the flames has been increased so the cask can be seen. In the actual fire simulation, and in a real fire, the flames are opaque.

The impact and thermal analysis results indicate that no accident involving the truck transportation cask would result in release of radioactive material or reduction in the effectiveness of the gamma shielding. The only radiological consequence of an accident would be exposure to external radiation from the cask because of a longer duration stop associated with the accident. The stop would require the emergency responders to clear the accident scene and to arrange for shipment resumption. In this situation the emergency responders will receive a radiation dose due to the radiation emitted from the cask. However, because there is no loss in effectiveness of the gamma shielding, the radiation dose to these responders is quite small.

For rail transport of spent fuel that is in an inner welded canister, the detailed impact and thermal analyses show there would be no release of radioactive material in any accident scenario evaluated. Only for very improbable impacts and long duration fires could there be a small reduction in the effectiveness of the lead gamma shielding, leading to an elevated external radiation level. This loss of lead shielding (LOS) would result in a maximum dose to a person 20 meters from the cask of $3x10^{-5}$ Sv and a collective population dose risk of less than $6x10^{-9}$ person-Sv per shipment for a typical shipment.

For rail transport of spent fuel that is not enclosed within an inner welded canister, there is the possibility for a small release of radioactive material following exceptionally severe (and improbable) impacts. The maximum dose risk to an individual from this release would be about 4.5×10^{-13} Sv. The maximum dose to an individual would be 1.6 Sv if the release actually occurred. The collective population dose risk is $5x10^{-7}$ person-Sv per shipment along the route with the largest population.

Similar to the routine transportation collective doses, the calculated collective dose risk from accidents has decreased with each successive risk assessment. Figure PS-6 shows a comparison of average collective doses from releases and loss of lead shielding from the three studies (NUREG 0170 did not calculate loss of lead shielding). This study also considered accident doses from a source that was not analyzed in the prior studies, the dose that results from accidents in which there is neither release nor loss of lead shielding, but there is increased exposure to a cask that is stopped for an extended period of time. Average collective doses for this scenario for the three casks studied are shown in Figure PS-7.This scenario is important because over 99percent of all accident scenarios do not result in either a release of radioactive material or a loss of shielding.

Comment [csb21]: What is this? First introduction of this term and needs to be expanded.

Comment [MF22]: Suggest being more quantitative. To some this may not be very reassuring.

Comment [csb23]: Agree.

Comment [s24]: States LOS "would result in a maximum dose to a person 20 meters from the cask", yet the Public Summary does not discuss (or at least I did not find) the significance of "20 meters"? Why wasn't 1 meter, 5 meters, or 40 meters selected as a basis for reporting? Also, note footnote on p. 17 and text indicates use of 30 m distance as typically as close as a person on the side of a road can get to a moving vehicle. I think the reason for the 20 m should be discussed / noted in the Summary. (CParks)

Comment [s25]: I think the concept of Sv is not well known by the general public and needs some explanation / reference point for public consumption. Typically this is done by indicating the dose in reference to background or in reference to some common activity - like a dental or chest x-ray. For example, the first time a Sv dose value is given in the Summary, there could be a footnote stating that the background dose is .0036 Sv/y or that one dental x-ray provides 4 x 10^{-5} Sv. Such reference is provided in Chapter 2 on p. 15, but it should be in Summary also. (CParks)

Comment [MF26]: First use of this term. It should be explained on first use.

Comment [csb27]: Per above comments, there is no context for this number. Do dose limits consider the exposure of first responders? A2 release limits are based on this, what about dose limits. May need to expand on some of this.

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Comment [csb28]: This splitting of hairs is not necessary and will not be viewed positively by the public.

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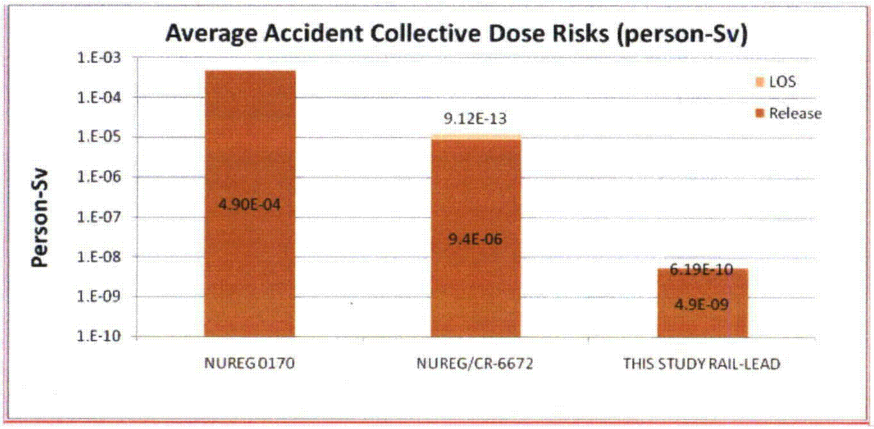

Figure PS-6. Accident collective dose risks from release and LOS accidents. The LOS bar representing the NUREG/CR-6672 collective dose is not to scale.

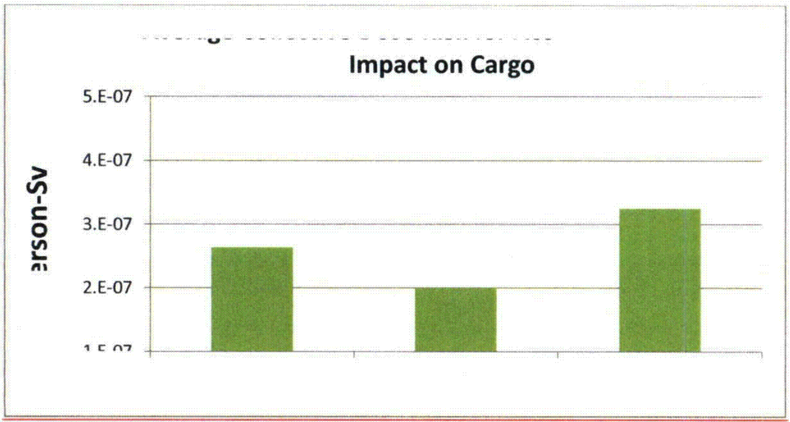

Figure PS-7. Average collective dose risk from accidents that have no impact on the cargo.

As noted above the purpose of this analysis was to reproduce (and in some cases extend) risk analysis previously considered in NUREG-0170 and NUREG/CR-6672 using updated models and methodologies. In the analysis completed the following conclusions were reached:

- The routes selected for this study are an adequate representation of U.S. routes for spent nuclear fuel. There were relatively few variations in the risks per km over these routes.
- The collective dose risks from routine transportation are vanishingly small. Theses doses are about four to five orders of magnitude less than collective background dose.

Comment [h29]: CLARIFICATION: What are the values above the columns for NUREG/CR-6672 and "THIS STUDY RAIL-LEAD"? are the numbers above the columns the loss of lead shielding values? Is that why there is no value above the NUREG 0170 column?

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Comment [h30]: EDITORIAL: Added this as a preface to the summary conclusions. It is important to frame the conclusions to ensure no over reach is claimed. The appropriate statement is that within the bounds of the updated analysis performed based upon the previous references, these conclusions can be drawn.

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Comment [csb31]: Huh? What does this mean?

Comment [csb32]: How is this conclusion supported by the discussion in this summary.

Comment [MF33]: This is the first discussion of the routes selected for the study. New information should not be presented in the summary.

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Comment [csb34]: Use a different word.

- Radioactive material would not be released in an accident if the fuel is in a welded canister in the cask, eliminating an already small transportation risk.
- Radioactive material would not be released for any accident involving a truck cask.
- Only rail casks without inner welded canisters would have any release in extremely severe accidents—99.999 percent of potential accidents will not result in a release of radioactive material from any cask.
- The collective dose risks for the two types of extra-regulatory accidents, accidents involving a release of radioactive material and loss of lead shielding accidents, are negligible compared to the risk from a no-release, no-loss of shielding accident.
- The risk of either a release or loss of shielding from a fire is negligible.
- These results are in agreement with previous studies.

The analyses and results described in this report confirm and extend the assurance provided by NUREG-0170 and NUREG/CR-6672 that spent fuel shipments can be completed safely, that the NRC regulations governing transportation of spent nuclear fuel are adequate, and the excellent safety record for spent fuel shipments will be maintained. It is also important to emphasize that in addition to the assurance provided by this overall risk assessment, specific spent fuel shipments are individually evaluated (both the cask, contents and route) to ensure individual shipments will not result in unacceptable risks to the public.

Finally, in addition to the extensive risk analysis and modeling of the results of credible accidents to spent fuel containers during transport (as described in this and previous analyses); extensive testing has been done and continues to be done on all casks proposed for and certified for use. In addition to the required tests, Sandia National Laboratory makes use of extensive facilities to test these casks under extra-regulatory accidents. Evidence of the robust nature of this packaging can be illustrated in the following Figures. In Figure 1, we see the drop test required for spent fuel. In Figure 2 is a test associated with a front end truck impact on a non-yielding surface. Figure 3 shows a side impact associated with train collisions. Finally, Figure 4 demonstrates a cask in an engulfing fire. The results of these tests in all cases indicates the robust nature of the cask to survive any reasonable and credible accident to be expected during spent fuel shipments.

Comment [h35]: EDITORIAL:I would qualify this. This says it is not possible. I have added qualifying words above that I suggest.

Comment [h36]: EDITORIAL:Changed "Will" to "Would".

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Comment [h37]: EDITORIAL:Changed "Will" to "would"

Comment [csb38]: This may not agree with our conclusions in the MacArthur maze Analysis. While these conclusions are probably true, I believe we need to state the "facts" and allow the members of the public to come to these conclusions.

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Comment [h39]: EDITORIAL:Changed "can" to "would"

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Comment [XXX40]: What about loss of neutron shielding?

Comment [h41]: EDITORIAL:Deleted "are not unexpected"

Deleted: not unexpected and are

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Comment [h42]: EDITORIAL:Revised wording

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Comment [csb43]: This study really cannot do this. Please revise.

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Comment [h44]: EDITORIAL:Added this

Comment [csb45]: Test is not required.

Comment [h46]: Added this and the Figures below. Please note – figures are for example purposes – SNL may wish to use other figures.

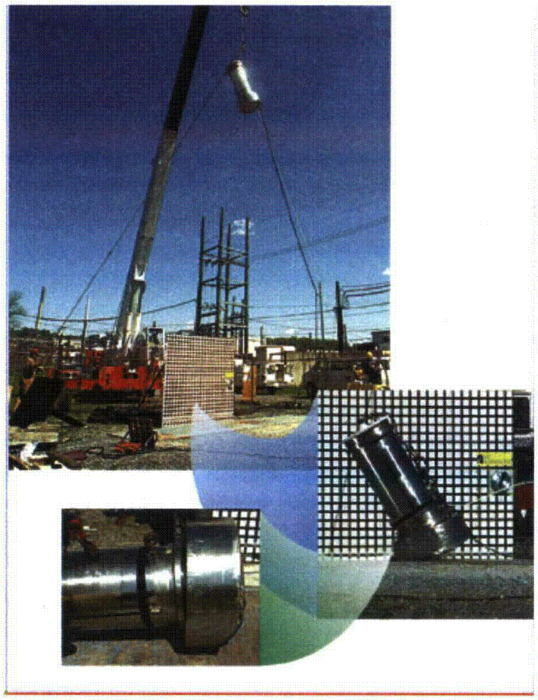

Figure 1 (Drop test of cask with associated minimal damage)

Comment [csb47]: Not sure if this is a spent fuel package.

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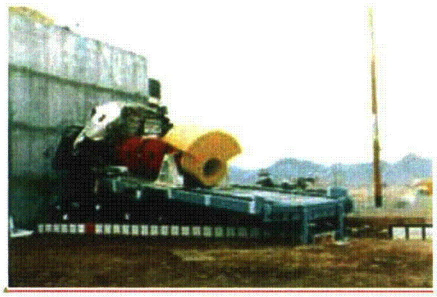

Figure 2 (Truck impact to unyielding surface – front end impact)

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Figure 3 (Side impact of cask by train)

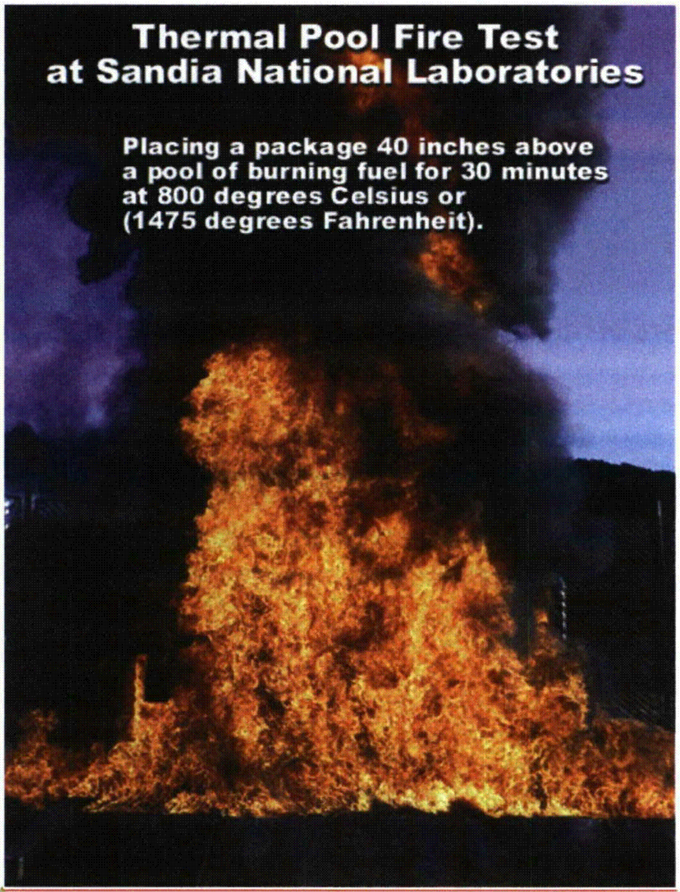

Figure 4 (Cask engulfed in thermal pool fire)

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