CHAPTER 1

INTRODUCTION

1.1 History and Purpose of this Analysis

The purpose of this study is analysis of the radiological risks of transporting spent nuclear fuel, in both routine transportation and transportation accidents. Using the latest available data and modeling techniques this study primarily analyzes cask behavior, rather than the behavior of the spent fuel being transported. This study is the latest in a series of assessments of this type and extends the scope of the series by analyzing the behavior of certified casks carrying fuel of known isotopic composition and burnup. The studies that preceded this one were based on conservative and generic assumptions.

This study is not intended to be a risk assessment for any particular transportation campaign, like transportation from reactors to a permanent repository. It also does not include the probabilities or consequences of malevolent acts.

The Nuclear Regulatory Commission (NRC) certifies casks used to transport spent nuclear fuel under Title 10 of the Code of Federal Regulations Part 71 (10 CFR Part 71). Part of the technical basis for this regulation was NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC, 1977), an environmental impact statement for transportation of all types of radioactive material by road, rail, air, and water. The conclusions drawn in NUREG-170 were:

- 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.
- The regulations in force at the time (1981) were "adequate to protect the public against unreasonable risk from the transport of radioactive materials." (46 FR 21629, April 13, 1981)

The risk assessment of NUREG-0170 was based on very conservative estimates of risk parameters, and on the imprecise analytical capabilities available at the time. The NRC concluded that the regulations were adequate because even very conservative estimates of risk parameters did not result in unacceptable risk. NRC also recognized that the agency's policies on radioactive materials transportation should be "subject to close and continuing review." In the spirit of continuing review, two comprehensive contractor reports dealing with spent fuel transportation have been issued since 1977: the Modal Study (Fischer et al., 1987) and NUREG/CR-6672 (Sprung et al., 2000)[1]. Both of these studies used advances in transportation risk assessment techniques to provide more accurate risk estimates. The Modal Study was the first intensive examination of vehicle accident statistics and was the first to organize the frequency of severe accidents by structural and thermal response of the cask. Using documented accident frequencies of large trucks and railcars, the Modal Study organized the probability of

Deleted: This study will use

Deleted: . It i

Deleted: s

Deleted: a study of

Comment [h1]: CLARIFICATION: This is not strictly true as assumptions associated with spent fuel release fractions must be made to determine the consequences of release accidents documented in Chapter/Appendix 5.

Deleted: .

Deleted: It is

Deleted: rounds out

Deleted: this series

Deleted: *the*

Formatted: Font: Italic

Deleted: from this environmental impact statement were

Deleted: models

Deleted: were

Comment [MF2]: Not sure what this words means here.

[1] "Modal Study" and "NUREG/CR-6672" are the names by which these documents are referred to in the general transportation literature. The actual titles are in the bibliography of this document.

H-1

accidents by the structural and thermal response of the casks in the accident. The Modal Study concluded that the frequency of accidents severe enough to produce significant cask damage was considerably less than NUREG-0170 had estimated. Although the Modal Study was not a risk analysis, since it did not consider the radiological consequence of accidents, risks less than those estimated in NUREG-0170 could be inferred.

Comment [MF3]: Not sure what this sentence is saying.

NUREG/CR-6672 built on the Modal Study by refining the mechanical stress/thermal stress combinations and recasting them as a matrix of impact speed and temperature. In addition, NUREG/CR-6672 developed expressions for the behavior of spent fuel in accidents and potential release of this material and analyzed the potential releases. The enhanced modeling capability available for NUREG/CR-6672 allowed analysis of the detailed structural and thermal damage to transportation casks. NUREG/CR-6672 also used results of experiments by Lorenz et al. (1980), Sandoval, et al. (1988), and Sanders, et al. (1992) to estimate releases of radioactive material from the fuel rods to the cask interior and from the cask interior to the environment following very severe accidents. The radionuclides available for release in the accidents studied in NUREG/CR-6672 are from relatively low burnup (30 gigawatt-days per metric ton of initial uranium [GWD/MTU]) and relatively high burnup (60 GWD/MTU) pressurized water reactor (PWR) and boiling water reactor (BWR) fuel, although the transportability of the high burnup fuel was not considered. NUREG/CR-6672 studied the behavior of two generic truck casks and two generic rail casks which were each composites of several certified casks.

The results of the NUREG/CR-6672 risk assessment were several orders of magnitude less than the estimates of NUREG-0170, and concluded that no radioactive material would be released in more than 99.99 percent of accidents involving spent fuel shipments. These low risk estimates resulted from the use of refined and improved analytical and modeling techniques, exemplified by the finite element analyses of cask structure, and some experimental data which were substituted for the engineering judgments used in NUREG-0170.

Deleted:

Comment [s4]: This is a true statement, but what is important from a dose perspective is the combination of burnup and cooling time - providing one without the other can appear as misleading. In addition, the reason these casks are limited to 45 GWD/MTU is not due to the cask design - the cask design could readily enable a larger source. It is the NRC concern about the integrity of fuel burned greater than 45 GWD/MTU that has caused a limit being set. The sentence and context seems to imply the cask design would not allow a higher burnup - I do not think that is true. I strongly suspect in the future that a licensee will come back to NRC requesting a higher burnup or shorter cooling time for these packages; thus leading to a higher dose closer to the regulatory limit. Since the dose results in the report are linearly proportional to the radiation source (except for release), a change in the contents to "push" values to regulatory dose limit at 2 m would not change results very much. I think some discussion of this point is warranted – but perhaps too confusing. (CParks)

The present study analyzes the behavior of three currently certified casks carrying Westinghouse 17x17 (PWR) fuel assemblies with 45 GWD/MTU burnup, the highest burnup that any of the three casks are certified to carry. The resulting radiological risks are less than those reported in NUREG/CR-6672. For routine transportation, the risks are slightly higher than those estimated in NUREG/CR-6672, because population densities along transportation routes have increased and traffic densities on the highways used for truck transportation have increased. For accidents, the radiological risks calculated in the current study are at least an order of magnitude less. The reduction in the estimates of risk from those in NUREG-0170 and NUREG/CR-6672 is the result of new data and observations and improved modeling techniques.

Comment [MF5]: The next sentence appears to contradict this sentence.

1.2 Risk

Risk provides an understanding of events that might happen in the future. Because risks are projections of potential future events, calculations of risk are estimates and based on approximations taken from historical or analytical data.

Comment [s6]: I think this para is poorly written. Mainly, I think it is "risk assessment" that helps provide an understanding of future events, not simple "risk". Secondly, "calculations of risk are estimates based on approximations taken from historical or analytical data."? So we are approximating historical data? And we can use "historical OR analytical data"? Perhaps, I'm mistaken, but I suggest a better construct to be: "calculations of risk are estimates based on actual historical data and analysis based on realistic assumptions regarding future events". (CParks)

Understanding transportation risk is integral to understanding the environmental and related human health impact of radioactive materials transportation. A large amount of data exists for deaths, injuries, and damage from traffic accidents. However, there are no data on health effects caused by radioactive materials transportation because no such effects have been observed. Therefore, both regulators and the public rely on risk estimates to gauge the impact of radioactive materials transportation. The risk estimates are projections of potential accidents and events, when and where they will happen, and how severe they will be. Risk estimates include estimating the likelihood and the severity of transportation accidents and the likelihood of exposure to ionizing radiation from routine transportation.

Risk is usually defined by answering the questions posed by the risk "triplet":

- What can happen (the scenario)?
- How likely is it (the probability)?
- What if it happens (the consequence)?

A risk number (quantitative risk) is calculated by multiplying the probability and consequence for a particular scenario. The probability of a scenario is always less than or equal to one. An event with 100% probability (i.e., probability = 1) of occurrence is an event that is certain to happen. In reality, very few events are certain to happen or certain not to happen (zero probability). The probability of most events is between these two extremes. For example, transportation accidents involving large trucks have a very low probability. The probability of a traffic accident is about 0.00001 per mile (or 1 in 100,000 miles) according to the Department of Transportation Bureau of Transportation Statistics (DOT, 2007), and the probability of a particular traffic accident scenario that includes vehicles carrying casks of radioactive material is much smaller still, as shown in the event trees in Appendix II of this document.

Deleted: (or we would hesitate to drive on the same freeway as a large truck)

Deleted: 1/100,000

Comment [MF7]: Not sure what *particular* means here. A truck carrying cask is no less likely to be in an accident, but it certainly is less likely to be in a severe accident. Please reword.

Comment [MF8]: There are no event trees in Appendix II. This may have supposed to have been Appendix V, but it is not clear to this reviewer where this information is in Appendix V either.

1.2.1 Accident Data

The only data available to estimate the future probability of a scenario are how often that scenario has occurred in the past. The frequency of the scenario can be considered the same as its probability. In the case of transportation accidents, enough accidents must have occurred that future accidents per kilometer can be predicted with reasonable accuracy. That is, the sample must be large enough to be sampled randomly. The most applicable frequency would be the frequency of accidents involving vehicles carrying spent nuclear fuel, but there have been too few of these for a statistically valid prediction.[2] Even accidents involving all hazardous materials transportation do not provide a large enough data base for statistical validity. The database used in this study is the frequency of highway accidents involving large semi-detached trailer trucks and the frequency of freight rail accidents (DOT, 2007). Freight rail accident frequency is based on accidents per railcar-mile.

Comment [MF9]: Word will not let me comment the footnote below, only the reference to it.

Do we know what percentage of rad shipments involve used (or spent) fuel? If so, then an estimate of the number of the 76 accidents involved Spent fuel. Obviously, the number would be <<1.

Comment [s10]: I could see the public asking "Why was non-US accident data not utilized?" Perhaps it is not worth a note in the report, but I know the first thing that came to my mind was the fact that other countries have had a LOT more experience with transportation of SNF than we have experienced in the US. So I sort of wondered "why not?" (CParks)

1.2.2 Spent Nuclear Fuel Transportation Scenarios

Transportation risk is categorized in this study by several scenarios, the most probable of which is routine transportation of spent nuclear fuel (SNF) without incidents or accidents between the

[2] The Bureau of Transportation Statistics lists accidents per year for all classes of hazardous materials. The 2009 database lists 76 class 7 (radioactive materials) rail and highway incidents and one Class 7 highway accident in the past ten years; http://www.phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/tenyr_ram.pdf. These data did not specify the type of radioactive material involved.

beginning and end of the trip. The risk associated with routine transportation is an example of the risk triplet:

- What can happen? The scenario is routine incident-free transportation.
- How likely is it? The probability is 99.999% (see Chapter 5).
- What if it happens? The consequence is a radiation dose less than one percent of background to individuals near the cask or along the route.

The doses and risks from routine transportation are analyzed in Chapter 2.

The accident scenarios discussed in this study are:

- Accidents in which the spent fuel cask is not damaged or affected.
  - Minor traffic accidents ("fender-benders," flat tires), resulting in minor damage to the vehicle. These are referred to as "incidents."[3]
  - Accidents where damage to the vehicle and/or trailer is enough that the vehicle cannot move from the scene of the accident under its own power, but does not result in damage to the spent fuel cask.
  - Accidents involving a death or injury, but there is no damage to the spent fuel cask.

  In these cases the only potential dose to the public is an increased residence time for individuals in the vicinity of external radiation emanating from the cask.

Comment [h11]: EDITORIAL:Inserted this

- Accidents in which the spent fuel cask is affected.
  - Accidents resulting in loss of lead gamma shielding but no release of radioactive material.
  - Accidents in which there is a release of radioactive material.

  In these cases there is either an increase in the potential external dose emanating from the cask, or an introduction of radioactive material into the environment with its consequent potential impact on the environment or internal/external exposure to individuals.

Comment [h12]: EDITORIAL:Added this.

Traffic accident statistics (accident frequencies) are used in the accident analysis to calculate risks from accidents. Average traffic accident frequencies since 1996 for large semi-detached trailer trucks are about two accidents per million highway kilometers (0.0019 per thousand km) and for freight rail, about one accident per ten million railcar kilometers (0.00011 per thousand railcar-km). The overall accident scenario probability is the product of the probability that an accident will happen (accident rate times distance) and the conditional probability that it will be a particular type of accident.

The consequence of an accident scenario is a dose of ionizing radiation, either from external radiation from a stationary cask or from radioactive material released in an accident. The risk is the product of the overall accident probability and the consequence, and is called "dose risk."

[3] In Department of Transportation parlance, an "accident" is an event that results in a death, an injury, or enough damage to the vehicle that it cannot move under its own power. All other events that result in non-routine transportation are "incidents." This document uses the term "accident" for both accidents and incidents.

1.3 Regulation of Radioactive Materials Transportation

Transportation of radioactive materials on public rights of way is regulated by the NRC under 10 CFR Part 71 and by the Department of Transportation (DOT), as part of hazardous materials transport regulations, under 49 CFR Parts 173 to 178. The regulations of 10 CFR Part 20 are also relevant. NRC transportation regulations apply primarily to the packages being transported. DOT regulations include labeling, occupational and vehicle standards, registration requirements, reporting requirements, and packaging regulations. In general, only the DOT packaging regulations apply to industrial and Type A packages, while both the DOT and the NRC regulations apply to Type A(F) fissile materials packages and Type B packages. Industrial and Type A non-fissile packages are designed for routine transportation and are not certified to maintain their integrity in accidents, though many do. Type B packages are used to transport very radioactive materials. They are designed to maintain their integrity in severe accidents because the NRC recognizes that any transport package and vehicle may be in traffic accidents. This study addresses the transportation of spent nuclear fuel, and thus concerns itself only with Type B packages.

Nuclear fuel that has undergone fission ("burned") in a reactor is both extremely hot and extremely radioactive when it is removed from the reactor. In order to cool thermally and to allow the very radioactive and short-lived fission products in the fuel to decay, the fuel is moved from the reactor into a large pool of water. The fuel remains in this pool for at least three to five years, until it can be remotely handled safely. The fuel usually remains in the pool as long as there is space for it. After the fuel has cooled sufficiently it can be removed from the pool to dry surface storage, either at the nuclear power plant or other location. Fuel is almost never transported before it has cooled for five years. The transportation casks used are rated for heat load. This rating often determines the cooling time needed for the fuel to be transported.

10 CFR Part 71

The NRC recognizes that vehicles carrying radioactive materials are as likely to be in accidents as any vehicles of similar size traveling on similar routes. Therefore transportation containers for very radioactive materials like spent nuclear fuel are designed to maintain their integrity in severe accidents[4]. Containers that can meet this requirement are Type B containers and include the casks considered in this analysis, the NAC-STC and Holtec HI-STAR 100 rail casks and the GA-4 legal weight truck cask.

Type B containers are designed to pass the series of tests described in 10 CFR 71.73, summarized below:

- A 30-foot drop onto an unyielding target. "Unyielding" in the test context means that the target is hard enough and heavy enough that the cask absorbs all the impact energy when it drops and the target does not absorb any impact energy. This is a test condition, meant to be more severe than an actual transportation accident. This drop is followed by

Comment [s13]: The words "very radioactive materials" is used here (and perhaps other places in report). This sounds pretty qualitative. I think more typically I've seen the wording "highly radioactive" used - perhaps just my personal preference. (CParks)

Deleted: highly

Deleted: .

Deleted: highly

Comment [s14]: I think this statement as written is simply incorrect. The inference of the statement is that a 3-5 year cooling time is needed before the fuel can be remotely handled. This is simply not true; much "hotter" fuel is and has been handled - otherwise how did it get to pool? Also, historically in this country and currently in other countries, fuel is transported with cooling times less than 3 to 5 years. (CParks)

Deleted: usually

Deleted: In the US, fuel

Comment [s15]: Similarly, Fuel is almost never transported before it has cooled for five years." True for the US, but not other countries. So, perhaps a few sentences are warranted on fact that part of the "best estimate" assessment in this report assumes continuance of current US practice - which does mean no removal from pool or transport prior to at least 3-5 years. (CParks)

Comment [MF16]: Is this always the case? Can't it be limited by dose rate. Suggest rewording as provided but if this is not the case, please disregard.

Comment [h17]: CORRECTION:Typo added "t"

Comment [h18]: EDITORIAL:I would replace this with the following: (meant to)….. "*simulate initial vehicular impact. This height corresponds to an impact velocity of ? for a hard target, and ? for a medium target, and ? for a soft target. As the preponderance of any accidents are associated with yielding surfaces either through impact with other moving vehicles, or due to orientation in which the rest of the vehicle yields prior to cask impact, this assumption is seen to be more severe than typical transportation accidents.*"

I think this is important to address as one of the most persistent complaints is the low drop height correspondence to actual vehicular speeds on impact.

Deleted: .

Deleted:

[4] Although release of a specific quantity of each radionuclide is allowed by regulation, Type B casks are typically designed to not release any material.

- A 40-inch drop onto a 6-inch-diameter steel cylinder to test resistance to punctures. This test is followed by
- A 1475 °F fire that fully engulfs the cask for 30 minutes.
- Immersion under three feet of water.

Figure 1-1 illustrates the sequence of tests the cask must be demonstrated to resist prior to being certified.

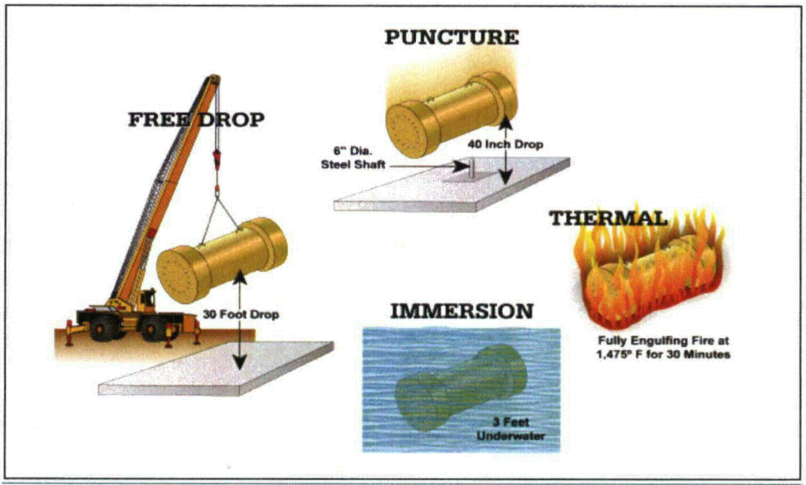

Figure 1-1. The four tests for Type B casks

The package tests in 10 CFR 71.73 are generally representative of a hypothetical accident. These tests are not intended to represent any specific transportation route, any specific historical transportation accident, or "testing to failure" for a specific package. These tests are intended to simulate the damaging effects of a severe transportation accident (but not all conceivable accidents) in a manner that provides international acceptability, uniformity, and repeatability.

The tests are performed on a package design. A package designer may create computer models to evaluate the performance of a package design and/or components of the package design, may build full-size or scale model packages for physical testing, or may incorporate reference to previous satisfactory demonstrations of a similar nature. In practice, the safety analysis performed for Type B casks often incorporates a combination of physical testing, computer modeling, and engineering evaluation. The packaging Safety Analysis Report (SAR) contains the information about the package design's performance in the tests and an evaluation against the acceptance criteria in 10 CFR 71. The SAR is used to apply for package cetification.

In addition to confirming that the tests were performed and that the package performance in the tests met the acceptance criteria, NRC staff reviews drawings to confirm that the safety-related aspects of the package are accurately described and conform to the design that was tested. Staff also reviews the acceptance criteria for packaging fabrication, to confirm that appropriate tests

Comment [MF19]: Eight hours is no longer part of the regulations. (Change in 1996)

Deleted: for eight hours

Deleted: four types

Comment [MF20]: If possible make the puncture test pin taller. It appears the impact limiters will impact the ground before the cask body impacts the puncture pin. Also number the tests to show sequence (1-drop, 2-puncture, 3-thermal, 4-immersion).

Deleted: conditions

Comment [s21]: To me it would be beneficial to explain that this "international acceptability" means these are the same tests (with minor variants) adopted by the IAEA and its Member State countries. (CParks)

Comment [MF22]: Add to acronym list

and criteria are specified for materials and components that affect package performance. Staff also reviews the operating instructions and maintenance program, which are part of the SAR. The operating instructions typically identify tests which must be executed or packaging components which must be inspected prior to making a shipment of the package. For example, visual inspection of welds, examination for dents or damage, and leak testing of the packaging are specified. The maintenance program typically addresses those items which must be periodically inspected, repaired or replaced.

Deleted: is a

Deleted: application

Deleted: in

Deleted: package

NRC relies on all of these types of activities to ensure the safety of transportation. "Production" model packages – those intended to be used for transportation in commerce – would not each be subjected to the Part 71 design tests. After the package had been through the tests, it is no longer in the pre-test condition. It is the pre-test condition package that is authorized for transport (IAEA, 2008).[5]

Deleted: go through

NRC regulations specify that total release of material from the cask over a period of one week following the tests can be no more than that allowed to be shipped in a non-accident resistant Type A package. The regulation also permits a maximum post-test external radiation dose rate of 0.01 Sv per hour.

Comment [MF23]: Where? At the package surface, etc.

Comment [MF24]: Because of some confusion of worst case vs. realistic, previous studies vs. this study, and the analytic vs. probabilistic parts of this study, it is recommended that the following tables (or reasonable facsimile thereof) be added to the report.

Test

10 CFR Part 20

This section of the Code of Federal Regulations prescribes the largest radiation dose that a member of the public should receive from NRC-licensed facilities, exclusive of background radiation, diagnostic or therapeutic radiation, or material that has been discharged to the environment in accordance with NRC regulation. These doses are:

- 1 mSv per year total effective dose equivalent (TEDE), including both external and committed internal dose.
- 0.02 mSv per hour in any unrestricted area from external sources. As Table 2-12 shows, the doses from routine, incident-free transportation are considerably below these limits.
- 5 mSv per year from a licensed facility if the licensee can show the need and expected duration of doses larger than 1 mSv per year.

Although the regulations state clearly that these dose limits do not include background, background provides a useful comparison to other sources of radiation exposure, since it affects everyone. The average background radiation dose in the United States is 3.6 mSv per year. This Part also regulates occupational doses to:

- 0.05 Sv per year TEDE
- 0.15 Sv/year to the lens of the eye
- 0.5 Sv/year to the skin.

[5] The authors are indebted to Michele Sampson of the NRC staff for the information on cask testing.

It is important to understand the relation of these regulatory accidents to the risk assessment provided in evaluations such as that contained herein. Relative to nuclear activities (such as spent fuel shipment), the NRC's charter is to quantify and regulate the risk of nuclear power to maximize its potential benefit to society while minimizing the associated risk. In this regard, it is the intention of this and other reports to argue for a position of reasonable and acceptable risk. The probability and consequence of accidents both are critical in determining what are reasonable levels of regulatory requirements for these activities. It is not the intent to prove accidents cannot and will not ever happen (or that a worse conceivable set of accident conditions can exist); rather that the risk from these activities is very low and can be argued to be far outweighed by the societal benefit of the associated nuclear activities. Consistent with these standards, the regulatory accident conditions are seen as a reasonable bound for testing and acceptance when judged against the likelihood of accident that extend well beyond these limits.

When judged in this light, and by any quantitative standard of risk, the use of nuclear power and its consequent ancillary activities such as spent fuel shipment are a very low risk to the public. There has never been a death associated with commercial nuclear power operations, or ancillary activities such as spent fuel shipment. There has neither been any documented cases of chronic or malignant illness associated with these commercial activities either. By these standards, all other dominant sources of power generation activities (fossil fuel, hydro) are far riskier activities to the health of the public.

Comment [h25]: EDITORIAL:Added this

1.4 Selection of Casks

Past generic risk assessments for the transportation of spent fuel have used generic casks with features similar to real casks, but generally without all of the safety features that are part of real cask designs. In this effort, the generic risk assessment is performed using actual cask designs with all of the features that contribute to their robustness. Because it is too costly and time consuming to examine all casks, a sub-set of casks was selected. Appendix I lists the various spent fuel casks that were certified by the NRC at the time the study began, provides the method of selecting the casks to be used, identifies the important features of the various cask designs, and concludes with the chosen casks.

Comment [MF26]: Not sure what *conservatisms* meant here. Replaced with *safety features*. May not be what the author intended.

Deleted: conservatisms

Table 1-1 lists the casks that were certified by the NRC as of 2006 (the date when the cask selections for this study were made) for the transportation of irradiated commercial light water power reactor fuel assemblies. Those above the heavy line are older designs that are no longer used, but still had valid certificates. Those below the heavy line are more modern and additional casks of these designs could be built. The casks for use in this study came from this last group. A brief description of each of these casks is included in Appendix I.

Table 1-1. NRC Certified Commercial Light Water Power Reactor Spent Fuel Casks

Cask	Package ID	Canister	Contents (Number of assemblies)	Type
IF-300	USA/9001/B( )F	No	7 PWR, 17 BWR	Rail
NLI-1/2	USA/9010/B( )F	No	1 PWR, 2 BWR	Truck
TN-8	USA/9015/B( )F	No	3 PWR	Overweight[a]

TN-9	USA/9016/B( )F	No	7 BWR	Overweight[a]
NLI-10/24	USA/9023/B( )F	No	10 PWR, 24 BWR	Rail
NAC-LWT	USA/9225/B(U)F-96	No	1 PWR, 2 BWR	Truck
GA-4	USA/9226/B(U)F-85	No	4 PWR	Truck
NAC-STC	USA/9235/B(U)F-85	Both	26 PWR	Rail
NUHOMS®-MP187	USA/9255/B(U)F-85	Yes	24 PWR	Rail
HI-STAR 100	USA/9261/B(U)F-85	Yes	24 PWR, 68 BWR	Rail
NAC-UMS	USA/9270/B(U)F-85	Yes	24 PWR, 56 BWR	Rail
TS125	USA/9276/B(U)F-85	Yes	21 PWR, 64 BWR	Rail
TN-68	USA/9293/B(U)F-85	No	68 BWR	Rail
NUHOMS®-MP197	USA/9302/B(U)F-85	Yes	61 BWR	Rail

[a]Overweight truck

The casks chosen for detailed analysis are the NAC-STC (Figure 1-2) and the Holtec HI-STAR 100 (Figure 1-3) rail casks. The GA-4 cask (Figure 1-4) will be used to evaluate truck shipments, but detailed impact analyses of this cask will not be performed because prior analyses of both truck and rail casks have shown that truck casks have significantly lower probability of release of radioactive material in impact accidents (Sprung, et al., 2000). _The impact analyses from Sprung et al. are used to assess the response of the GA-4 cask. The complete Certificates of Compliance (as of April 12, 2010) for each of these casks is included in Appendix I. The NAC-STC cask was chosen because it is certified for transport of spent fuel either with or without an internal welded canister. Its certificate of compliance allows use of either elastomeric o-rings or metallic o-rings. Even though there are five casks in the group that use lead as their gamma shielding, of this group only the NAC-STC can transport fuel that is not contained within an inner welded canister. This ensures (as noted in the analysis contained in Chapters 3-5) that a maximum potential for radioactive release to the public is considered in the present risk analysis. The HI-STAR 100 rail cask is chosen because it is the only all-steel cask in the group that is certified for transport of fuel in an inner welded canister. The GA-4 truck cask is chosen because it has a larger capacity than the NAC-LWT truck cask, and therefore is more likely to be used in any large transportation campaign.

Comment [h27]: EDITORIAL:Added this.

The choice of rail casks allows comparison between directly loaded and canistered fuel, comparison between a steel-lead-steel cask and an all-steel cask, and comparison between elastomeric o-ring seals and metallic o-ring seals.

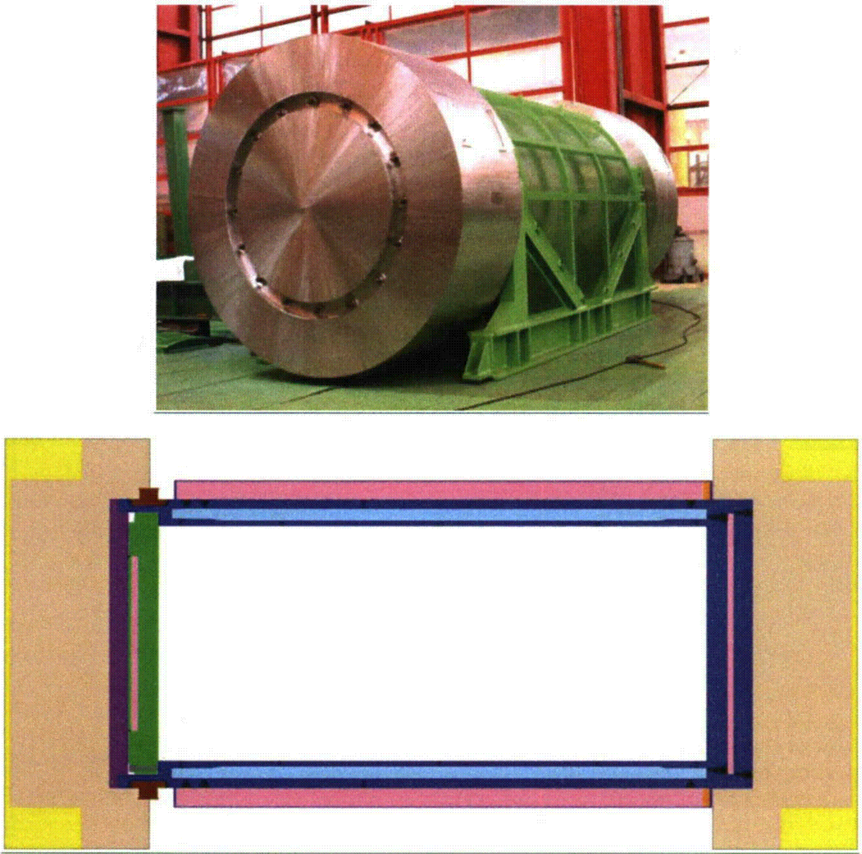

Figure 1-2. NAC-STC cask (courtesy of NAC International)

Comment [h28]: EDITORIAL: If this graphic is included it should be annotated to identify the relevant features. If not, it is more confusing than helpful.

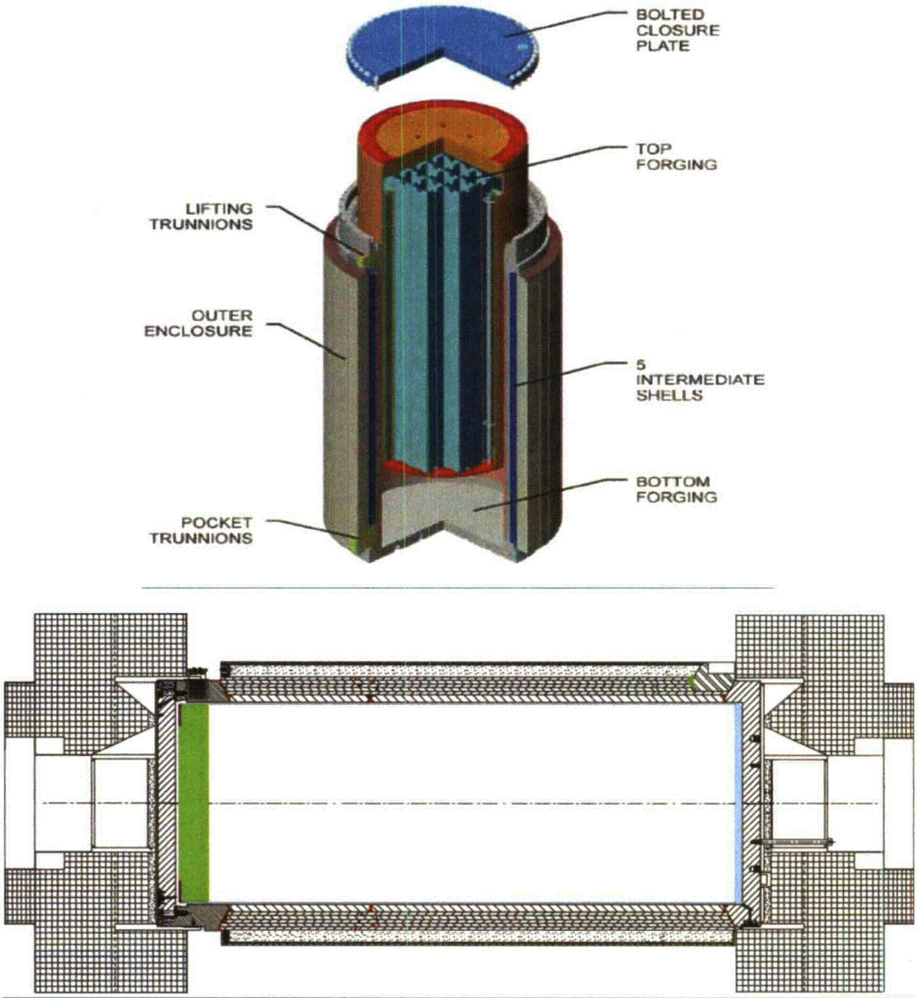

Figure 1-3. Basic layout of the HI-STAR 100 rail transport cask (from Haire and Swaney, 2005, and Holtec International, 2004)

Comment [h29]: EDITORIAL:Again this would be far more useful if major components were annotated on this graphic. What does the green bar represent?

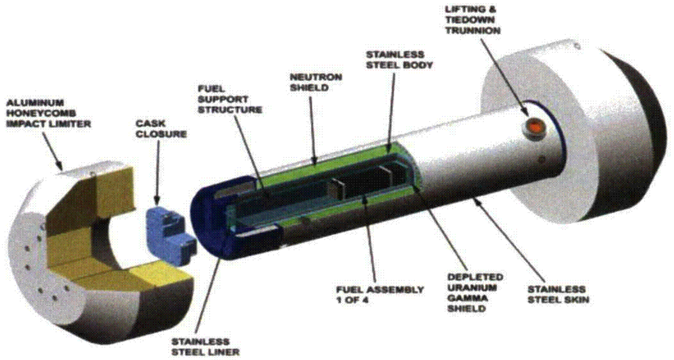

Figure 1-4. GA-4 cask (courtesy of General Atomics)

The NAC-STC rail cask is chosen because of the flexibility of its Certificate of Compliance. This cask can be used for both directly loaded fuel and for canistered fuel and is certified with either elastomeric or metallic o-rings. The HI-STAR 100 rail cask is chosen because it is the more modern of the two all-steel walled casks. The GA-4 truck cask is chosen because it has a higher capacity and has depleted uranium (DU) shielding. The chosen casks include all three of the most common shielding options; lead, depleted uranium, and steel.

Deleted: (DU)

The detailed analyses of this report use the geometry and properties of these specific casks, but other similar casks are likely to respond in the same manner as these casks. Therefore, in the rest of this report the HI-STAR 100 rail cask will be referred to as Rail-Steel, the NAC-STC rail cask will be referred to as Rail-Lead, and the GA-4 truck cask will be referred to as Truck-DU.

Comment [h30]: EDITORIAL:Although well described here, a table that indicates the individual casks and their principle reason for consideration may be useful here

1.5 Organization of this Report

Each chapter in this study, except Chapter 6 (Observations and Conclusions), has an associated appendix that describes the analytical methods and calculations used to arrive at the results discussed in the chapters. Descriptions of programs, calculations and codes used are in the relevant appendices.

Deleted: .

Deleted: the conclusions

1.5.1 Chapter 1 and Appendix I

This chapter provides an introduction to the study, a brief background discussion, a discussion of risk as applied to transportation of radioactive materials, a discussion of cask selection, and a review of the organization of the report. Appendix I contains details about the cask selections and the Certificates of Compliance of the selected casks.

1.5.2 Chapter 2 and Appendix II

Chapter 2 and Appendix II discuss the RADTRAN analysis of incident-free transportation. During routine ("incident-free") transportation, spent fuel transportation packages deliver an external dose. This chapter describes the consequence of the external dose. In previous spent fuel transportation risk studies the regulatory maximum dose rate, 0.1 mSv/hour at 2 meters from the cask, was assumed to be the external dose rate from every intact cask evaluated in the particular study. As part of the stated charter of this assessment to provide a more realistic estimate of the assumed risks, the present study uses the external dose rate from commercial certified casks as reported in the SAR of those casks.

Deleted: most

Comment [h31]: EDITORIAL: Added this.

Deleted: The

Deleted: Safety Analysis Reports

1.5.3 Chapter 3 and Appendix III

Chapter 3 and Appendix III address the structural analyses used to determine the cask response to accidents and the parameters that determine loss of lead gamma shielding and releases of radioactive material. The results of detailed analyses of impacts onto rigid targets at speeds of 48, 97, 145, and 193 kph (30, 60, 90, and 120 mph) in end, corner, and side-on orientations are given. Results for impacts onto other surfaces or other objects are also provided. The response of the fuel assemblies carried by the casks is also discussed.

1.5.4 Chapter 4 and Appendix IV

Chapter 4 and Appendix IV address the thermal analyses used to determine the cask response to these accidents and the parameters that determine loss of lead gamma shielding and releases of radioactive material. The results from analyses of fires that completely engulf the cask and fires that are off-set from the cask are given. The temperature response of the cask seals, the shielding material, and the spent fuel is provided.

1.5.5 Chapter 5 and Appendix V

Chapter 5 and Appendix V address the RADTRAN analysis of transportation accidents, development of accident event trees and conditional probabilities, development of the radionuclide inventory and radioactive materials releases and dispersion of released material in the environment. The chapter also discusses accidents in which there are no releases – the most likely accidents – in which the radioactive cargo is not affected at all, and an essentially undamaged cask and its conveyance (which may be damaged) sit for many hours at the accident location.

1.5.6 Chapter 6

Chapter 6 summarizes the results of all the analyses and includes a comparison between NUREG-0170 (NRC, 1977), the Modal Study (Fischer et al., 1987), NUREG/CR-6672 (Sprung et al., 2000) and this study.

1.5.7 Bibliography

The bibliography is placed after the appendices. It contains all cited references and other bibliographic material. Citations in the text (e.g., Sprung et al., 2000, Figure 7.1) include specific page, figure, or table references where appropriate.