Radiation Doses to the Public From the Transport of Spent Nuclear Fuel

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Abstract

This paper reviews issues that have been raised concerning radiological risks and safety of the public exposed to shipments of spent nuclear fuel and high-level radioactive waste to a Yucca Mountain repository. It presents and analyzes the contrasting viewpoints of opponents and proponents, presents facts about radiological exposures and risks, and provides perspective from which to observe the degree of risk that would devolve from the shipments. The paper concludes that the risks to the public's health and safety from being exposed to radiation from the shipments will not be discernable.

Introduction

Much has been printed and said about the risks to members of the public from exposures to radiation emanating from shipping casks that transport spent nuclear fuel, high-level radioactive waste, and other radioactive materials. In comments to the public, the State of Nevada's Nuclear Waste Project Office (NNWPO) has suggested that the regulatory limit of 10 millirem per hour 2 meters from the side of transport vehicles results in unacceptably high exposures to members of the public. Mr. Robert Halsted, speaking for the NNWPO, has presented verbal pictures of radiation exposure to pregnant women in vehicles caught in traffic gridlock next to shipments. At the Waste Management 2002 meeting in Tucson, Arizona, Mr. Halsted estimated that a worker at a truck stop where shipments to Yucca Mountain stopped to refuel could receive an annual dose up to 1 rem. Others have suggested there will be environmental justice impacts in minority communities along routes where there will be exposure to radiation from passing shipments. Mr. Halsted, again speaking for the NNWPO, has called shipments of spent nuclear fuel and high-level radioactive waste "rolling x-ray machines that you cannot turn off."

When the subject turns to transportation accidents, the State of Nevada and others have called shipments of spent nuclear fuel "mobile Chernobyls." The State of Nevada commissioned a study that estimated thousands would die if a rail shipment of spent nuclear fuel were involved in an accident such as the July 2001 accident that occurred in the Baltimore Tunnel in Baltimore, Maryland. The State's projections of consequences of radiation doses to the public that could result from an act of sabotage have been even more dramatic.

Several of those commenting on DOE's *Draft Environmental Impact Statement for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (DOE 1999) expressed concern regarding contamination of community water reservoirs as the result of an accident. In public comments to the U.S. Nuclear Regulatory Commission (NRC), Mr. Halsted stated that if a spent nuclear fuel assembly dissolved in Nevada's Lake Mead, the resulting levels of radioactivity would exceed the U.S. Environmental Protection Agency's (EPA's) drinking water standards. Others have expressed concern about the use of barges to transport casks on the Great Lakes and the radiological consequences for the lakes if there were an accident. In addition, the State of Nevada has argued that the cost of cleanup following an accident or act of sabotage would be extreme – exceeding $10 billion. Mr. Halsted has suggested that accidents with these consequences can be expected to happen. In its report – "A Mountain of Trouble" – the State estimated that as many as 350 accidents would occur in transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain. The City of North Las Vegas estimated that $5 billion of economic development along the northern Las Vegas Beltway would be lost because of the public's perception of risks from radiation released in transportation accidents that could occur during shipments to Yucca Mountain.

At the same time, DOE's *Final Environmental Impact Statement for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada* (YM EIS) (DOE 2002) presents an exhaustive analysis of the potential radiological impacts to members of the public from shipments of spent nuclear fuel from 77 sites to Yucca Mountain. This analysis shows that the total impacts to 11 million to 16 million people who live along truck and rail routes that could be used would be small – between 2 and 5 latent cancer fatalities over 24 years. These impacts fall below the 1-in-1-million threshold used by the EPA to identify environmental issues of concern. In effect, the impacts estimated by the YM EIS could not be discerned in the affected population where the annual rate of fatalities from all causes is about 10,000 per 1 million.

The risks associated with accidents analyzed in the YM EIS are far lower than the very low radiological risks from routine transportation. Even when probability is removed from consideration, the YM EIS estimated that the consequences of a maximum reasonably foreseeable rail accident occurring in the center of a highly populated metropolitan area would be 5 latent cancer fatalities in a population of 5 million. In making this estimate, DOE made a number of conservative assumptions, including the assumption that people would not be evacuated from contaminated areas for a year following the accident. Of interest is that the analytical conditions for the maximum reasonably foreseeable accident analyzed are comparable to the most severe conditions reported for the Baltimore Tunnel fire.

Clearly, the State of Nevada and DOE have drawn substantially and dramatically different conclusions about radiological safety of the public from the same base of information about future shipments to a nuclear waste repository at Yucca Mountain, Nevada. Thus, it is necessary to look into the source information in an attempt to understand these differences.

Regulatory requirements

Spent nuclear fuel or high-level radioactive waste will be shipped in casks that are certified by the NRC in accordance with the requirements in Title 10 Part 71 of the Code of Federal Regulations. This is important. It means that the casks will meet a suite of performance requirements that have been selected to protect public health and safety. Included are requirements limiting radiation dose external to the cask for normal conditions of transport and following accidents. In addition, the cask must include features that prevent the occurrence of nuclear criticality under normal and accident conditions, and it must contain its radioactive material contents when subjected to a sequence of drop, puncture, fire, and immersion accident tests.

In addition, the U.S. Department of Transportation (DOT) regulates shipments of radioactive materials, including spent nuclear fuel and high-level radioactive waste. These regulations are contained in Title 49 of the Federal regulations. The DOT regulations include requirements for selecting highway routes (although routes for shipments of spent nuclear fuel must also be approved by the NRC); expediting shipments; setting surface contamination limits on shipping casks and vehicles; establishing radiation dose rates external to casks and vehicles; enhancing the safety of rail, truck, and maritime transportation; and using NRC-approved casks. The DOT regulations establish the limit of 10 millirem per hour 2 meters from the side of a transport vehicle for exclusive-use transport of radioactive materials. Dose rates in normally occupied areas of a transport vehicle cannot exceed 2 millirem per hour unless the vehicle operators' exposures are managed under a radiation protection program.

Dose to individuals from a single shipment during routine transportation

Assuming that the dose rate 2 meters from the side of a shipment is the regulatory limit of 10 millirem per hour, the dose to a person 30 meters (about 100 feet) from the side of a highway or railroad where the shipment passes can be easily calculated. One only needs to know the dimensions of the shipping cask and the speed that it is transported along the road/rails. Assuming a speed of 55 miles per hour, the dose to a person 30 meters from a route from a single passing shipment of commercial nuclear reactor spent fuel would be about 0.07 microrem. For perspective, this can be compared to the average individual dose in the continental United States of about 41 microrem per hour, or about 0.01 microrem per second, from natural background radiation. Also, assuming that one-half of the dose from the passing shipment is neutron radiation and that a 100-square-centimeter detector/counter having 100 percent efficiency is used, on average 1 neutron would be detected (above background) as the shipment passed. Background neutron radiation resulting from natural environmental processes and sources—such as alpha decay of radon gas in the atmosphere, naturally occurring radium in soil, spontaneous fission decay of natural uranium in soil and rock, and cosmic radiation—would probably mask the neutron radiation from a passing shipment.

All of the above assumes that the dose rate external to a shipment would be the maximum allowed by regulations and that the shipments would travel at 55 miles per hour. It is unlikely that the dose rate will be the maximum allowed by regulations. One reason is that it will be common-sense practice for shipping facilities to ensure that the dose rate external to shipments is some reasonable margin below the regulatory limit to allow for uncertainties in measurements.

However, shipments could travel at speeds slower than 55 miles per hour, especially rail shipments. Assuming the travel speed is 20 miles per hour and that the dose rate is the maximum allowed by regulations, the dose from a single passing shipment would be about 0.16 microrem to a person 30 meters away – about 2.3 times the dose for a shipment that passed at 55 miles per hour.

For persons who are in vehicles traveling along the same route as a truck shipment, the dose to an individual would be greater than that for a person along the roadway. Assuming that personal automobile traffic flows at a speed about 5 miles per hour faster than the shipment and that a person in a passing automobile traveling in the same direction is an average distance of 2 meters from a shipment when passing occurs, the dose received would be about 6 microrem. Persons in vehicles passing in the opposite direction would receive much lower doses.

For those who might be locked in traffic gridlock with a shipment vehicle next to (closer than 2 meters from) the automobile or bus in which they are riding, the YM EIS estimates the dose could be as high as 16 millirem. This dose assumes the person would be exposed for 1 hour with the side of the transport vehicle carrying spent nuclear fuel less than 4 feet away. The analysis also assumed that the dose rate external to the transport vehicle would be the maximum allowed by regulations. For perspective, a dose of 16 millirem is approximately the same as the dose one receives from two chest x-rays. It is also about 5 percent of the average annual background radiation dose to individuals in the continental United States. It is also comparable to the dose a pregnant woman and her fetus would receive if she made two round trips flights from New York to Los Angeles.

Doses from single shipments occur not only to persons in traffic with the shipment and to persons who live along the shipping route, but also to people who live near places where shipments stop. Rail shipments stop to allow a change of train crews, classification and blocking of rail consists in rail yards, and periodic inspections en route. Truck shipments stop for walkaround inspections, state inspections, rest breaks for drivers, and vehicle refueling. Most stops would occur in rural areas or in areas where there was substantial separation between shipments and nearby communities. For rail classification stops, if general freight service were used, stops could be as long as 48 hours and over weekends and holidays.

The YM EIS assumes that rail shipments would stop an average of 30 hours at origin and destination classification rail yards and that the time spent in en-route stops for classification and inspection would be 0.033 hour per kilometer of travel (a rate equivalent to about one classification stop for each 600 miles of travel). The time spent by rail shipments at stops is estimated to exceed the travel time; therefore, the YM EIS analysis estimated that a significant fraction of the dose to the public along rail routes would be to persons who live in the vicinity of locations where shipments would stop. If a member of the public stood for 30 hours at a location in a rail yard 200 meters (1/8 mile) from a shipment, and if there were no intervening structure or topography, and if shielding effects of the atmosphere were discounted, the total dose to the individual would be about 90 microrem. Again, this assumes the dose rate external to the rail car is the maximum allowed by regulations. Assuming the linear no-threshold hypothesis correlation of the risk of suffering a fatal latent cancer (a rate of 0.0005 latent cancers per rem of dose to a population), a dose of 90 microrem would increase the probability of the exposed individual suffering a fatal cancer from about 23 percent to about 23.000005 percent.

For truck shipments, the dose to members of the public at truck stops is a significant fraction of the total dose that would occur along the shipment route. A study of truck stop times conducted by Sandia National Laboratories (Griego et al. 1996) collected observations of the numbers of persons near to trucks at stops and the time required for a stop. Based on the results of this study, the average stop time for trucks was about 19 minutes, with the longest observed time being 49 minutes. Because there is a continuous flux of people at a truck stop, the Sandia study reported observations of the average number of people at specified distances from a truck during the time the truck was at the stop. Based on the reported data, there are on average six people at an average distance of 16 meters from a truck when it is stopped. Assuming that an individual in this group is fueling an automobile for 10 minutes while a spent nuclear fuel shipment is 10 meters away, the dose received by the individual would be about 300 microrem. The dose to a truck stop worker 20 meters away from a shipment that stopped for 19 minutes would be about 160 microrem. These estimates assume that there are no intervening structures or vehicles that would provide shielding and that the dose rate external to the shipment would be the maximum allowed by regulations.

Table 1 summarizes doses to members of the public that could occur in the course of routine transportation of spent nuclear fuel, high-level radioactive waste, or other exclusive-use shipments of radioactive materials. For perspective, the table also lists doses from other radiation sources to which members of the public are routinely exposed.

Dose from an accident

In 2000, Sandia National Laboratories and the NRC published a reanalysis of the performance of shipping casks in severe transportation accidents (Sprung et al. 2000). The report concluded that casks used to transport commercial spent nuclear fuel that were designed, manufactured, and operated in accordance with NRC regulations in Title 10, Part 71 would survive more than 99.99 percent of all accidents without releasing their contents. In addition, the report presented estimates of cask performance under a series of severe accident conditions (categories of accidents) that would be expected to occur less than once in 10,000 accidents. The severe accident conditions were categorized according to ranges of effective speeds of impact and cask body temperatures following exposure to fire. The estimates of releases were coupled with estimates of the likelihood of occurrence for each of 18 categories of severe truck and 20 categories of severe rail accidents.

In a recent report released to the press, the State of Nevada presents data, based on DOE analyses, that suggests that releases, particularly of radiocesium, would be dramatically greater than estimates presented by Sprung for equivalent accidents. However, on close examination, the argument for using the observed fraction of total radiocesium leached from broken-up spent fuel rods as a basis to escalate the amount of the isotope that would be volatilized from ruptured cladding is flawed. The report claims to use DOE data as its basis for estimating that as much as 9 percent of total radiocesium could be deposited in fuel rod gaps and compares this to the estimate of 0.3 percent used in the Modal Study (Fischer 1987). These two sets of values are then used to escalate the cesium release fraction by a factor of 30 for severe transportation accidents that involve fire. What is

Table 1. Dose from a single truck or rail shipment of spent nuclear fuel, high-level radioactive waste, or other exclusive-use shipments of radioactive material

Individual	**Transportation condition**	**Dose** [1, 2]
Person 30 meters from route	55 mph passing	0.00000007 rem (0.07 μrem) probability of LCF 3.5×10^{-11}
	20 mph passing	0.00000016 rem (0.16 μrem) probability of LCF 8×10^{-11}
Person in automobile	5 mph passing traffic	0.000006 rem (6 μrem) probability of LCF 3×10^{-9}
	Stopped 1 hr in traffic gridlock	0.016 rem (16 millirem) probability of LCF 8×10^{-6}
Person living near rail classification yard	Shipment stopped for 30 hours @ 200 meters	0.000090 rem (90 μrem) probability of LCF 4.5×10^{-8}
Person fueling auto at truck stop	10-minute stop @ 10 meters	0.0003 rem (300 μrem) probability of LCF 1.5×10^{-7}
Truck stop worker	19-minute stop @ 20 meters [3]	0.000160 rem (160 μrem) probability of LCF 8×10^{-8}
Airline passenger exposed to elevated levels of cosmic radiation	Round trip from New York to Los Angeles	0.007 rem (7 millirem) probability of LCF 3.5×10^{-6}
Average individual in United States exposed to all sources of background radiation	1-second exposure to natural background radiation	0.00000001 rem (0.01 μrem) probability of LCF 5×10^{-12}
	1-hour exposure	0.000041 rem (41 μrem) probability of LCF 2×10^{-8}
	1-year exposure	0.36 rem (360 millirem) probability of LCF 1.8×10^{-4}
	Lifetime exposure to natural background radiation (70 years)	25 rem probability of LCF 1.3×10^{-2} (1.3%)

1. Assumes dose rate external to shipment equals regulatory limit of 10 millirem per hour 2 meters from vehicle side.
2. LCF estimates based on linear no-threshold model with a factor of 0.0005 LCFs per rem of exposure to a population.
3. Stop time for truck stop worker dose based on average of observations by Griego et al. 1996.

ignored is the fact that the amount of radiocesium released in a fire accident is not the total radiocesium present. Rather, it is the material that is in vapor phase in fuel rod gaps and plenums carried out by gases being released through rod ruptures. The vapor pressure of cesium is so low that, following initial blowdown release, evolution of volatile cesium from rods would be exceedingly slow and would not contribute measurably to total releases from a cask.

The analysis of the risks of exposure to releases resulting from transportation accidents presented in the YM EIS used (1) the data presented by Sprung, (2) accident rates in each state shipments would cross (Saricks and Tompkins 1999), (3) the distance shipments would travel, and (4) the estimated number of shipments that would be made to Yucca Mountain. The analysis estimated that there could be as many as 67 truck accidents in the course of about 50,000 truck shipments or 8 rail-car accidents in the course of about 10,000 rail-cask shipments. These estimates were for respective scenarios wherein shipments of 70,000 metric tons of heavy metal (MTHM) of spent nuclear fuel and high-level radioactive waste to Yucca Mountain would be made mostly by truck or mostly by rail. Based on these results and on the probability of a transportation accident that would be severe enough to cause a release of radioactive materials, the likelihood of an accident that would have any release would be about 0.007 over 50,000 truck shipments and 0.00008 for 10,000 rail shipments.

For accidents where there could be releases, as would be expected, the amount of gases, volatile radionuclides (including cesium), particulates, and crud released increases as the combined fire and impact forces increase. However, based on truck and rail accident statistics, the probability of an accident occurring decreases dramatically as the severity of accident conditions increases. Because the estimates of risks of releasing radioactive materials from casks in accidents are so low, DOE does not expect that any of the projected accidents would be severe enough to release radioactive materials. In fact, the risk of release is so low that the risk of dose to populations living near locations of accidents in which shipping casks would be undamaged (99.99 percent of accidents) from normal radiation external to a cask while it is being recovered is comparable to the radiological risk of releases. Even so, the dose to an individual living 30 meters from the accident scene where an undamaged cask was being recovered would be small – about 100 microrem.

Because it is useful to understand the magnitude of consequences that could result from the most severe of accidents that can be reasonably foreseen, the analysis in the YM EIS evaluated so-called maximum reasonably foreseeable transportation accidents. Such accidents are defined by DOE internal guidance as accidents that would have a probability of occurring more often than once in 10 million years. To identify the maximum reasonably foreseeable accident, the YM EIS analysis evaluated the consequences of all of the severe accidents identified by Sandia (Sprung et al. 2000), then selected the accident that would have an annual probability of occurring greater than 0.0000001 (1×10^{-7}) and that would lead to the greatest consequences. In selecting this accident, the analysis considered the probability that it would occur in highly populated urbanized areas and under weather conditions that would lead to the greatest consequences. The most severe accidents that satisfy all of these conditions for both truck and rail shipments were those involving long-duration fires, such as the Baltimore Tunnel fire.

For the conditions analyzed, and assuming that evacuation and other remedial measures would not be taken for at least 1 year following the accident, the analysis of a maximum reasonably foreseeable rail accident estimated the exposed population would receive a dose of about 10,000 person-rem, resulting in an estimated 5 latent cancer fatalities. The analysis estimated that the 50-year committed dose to a maximally exposed individual would be about 29 rem. A dose of 29 rem would increase an individual's risk of a latent fatal cancer from about 23 percent, the rate for fatal cancers from all causes, to about 24.5 percent. For an accident involving a truck cask, the results were about $1/9^{th}$ those for the rail cask accident; as might be expected, this roughly correlates to the ratio of the contents of the two kinds of casks.

Accidents with greater consequences are analyzed in the YM EIS. But, the next most likely rail and truck accidents that also have greater consequences are estimated to be 100 times less likely to occur than the already very unlikely maximum reasonably foreseeable accidents.

The YM EIS also considered the potential for severe accidents involving transportation of spent nuclear fuel in casks transported by barges. Because the total annual distance traveled by barges for shipments from reactor sites to nearby railheads would be limited, accidents that could lead to release of radioactive materials would not to be reasonably foreseeable. Nonetheless, the YM EIS concluded that even if radioactive materials were released in a barge accident, the dose to members of the public would be much less than for accidents where radioactive materials were released to the atmosphere. In responses to public comments, DOE observed that spent nuclear fuel is a solid ceramic clad in a corrosion-resistant metal tube and that it cannot be easily dispersed into the environment. Further, spent nuclear fuel, which has been exposed to the high-temperature water environment of a nuclear reactor followed by years of storage in a water pool, does not dissolve in water and therefore could not be readily dispersed from a shipping cask into waters used by the public for recreation and drinking.

In considering the maximum reasonably foreseeable accidents, the State of Nevada has argued that DOE should assume that the spent fuel being shipped has been discharged from the reactor for 5 years. In contrast, based on an analysis of the expected stream of spent fuel that would be delivered from reactor sites, the DOE analysis assumed the fuel would be 15 years old. In reality, because 5-year cooled fuel would constitute only a small fraction of the fuel shipped to Yucca Mountain, the annual probability of severe accidents involving this fuel would be less than 1 in 10 million. Also, even if considered in the analysis, the capacity of shipping casks would be less if carrying 5-year cooled fuel than the capacity would be for casks carrying the assumed 15-year cooled fuel. Thus, the increase in radionuclide content of 5-year cooled fuel would be offset by the reduction in cask capacity to accommodate this fuel. In effect, the assumptions suggested by the State of Nevada would not lead to results that differed significantly from those estimated by DOE.

In comments to DOE, the State of Nevada and others expressed concern for the safety of emergency response personnel who are first to arrive at the scene of an accident. As a consequence, in the YM EIS, DOE estimates the radiological risks to emergency personnel who are first on the scene of an accident. Because there is a very small likelihood that the contents of a cask would be released in an accident, the expected dose to a first responder who follows DOT's North American Emergency Response Guidebook (published by the American Trucking Associations) would be small. The guidebook recommends that responders assess the accident scene and report the information immediately to a "radiation authority"; approach an accident from upwind; stay clear of all spills, vapors, fumes, and smoke; remove injured persons from the scene; isolate a potential spill or leak area 25 to 50 meters in all directions; keep unauthorized persons away from the area; and move a safe distance upwind from the accident scene until additional assistance arrives.

The analysis in the YM EIS considered that responders could receive a dose as high as 2.6 millirem at accidents in which a cask's shielding was not damaged. A dose of 2.6 millirem is approximately equal to the average dose from natural background radiation received by individuals in the continental United States in 2.5 days. In the case of maximum reasonably foreseeable severe accidents where impact forces or fire could lead to loss of lead shielding in a rail cask, the analysis in the YM EIS estimated that a first responder unaware of a cask's reduced shielding could receive a dose as high as 0.83 rem. Such conditions are very unlikely, having a frequency of occurring of about 1 in 1 million years. A dose of 0.83 rem would lead to an increased risk of an individual in the United States suffering a fatal cancer from about 23 percent from all causes to about 23.04 percent.

Table 2 summarizes the estimates of doses to populations and individuals that could result from accidents involving shipments of spent nuclear fuel to individuals. The table also presents estimates of the risk of latent cancer fatalities from the received doses. For perspective, the table presents estimates of the number of individuals who could be killed in traffic accidents involving the shipments.

Table 2. Dose to individuals from accidents in transporting spent nuclear fuel

Accident	Transport mode	Number or frequency	Individual or population	Dose and dose risk
All accidents – no release expected	Truck	67 per 50,000 shipments – about 3 per year if most shipments to Yucca Mountain are by truck	General public within 80 kilometers of route – about 11 million live within 800 meters of route	~0.5 person-rem for 50,000 shipments probability of LCF 2.5×10^{-4}
	Rail	8 rail car accidents per 10,000 shipments – about 1 every 3 years if most shipments to Yucca Mountain are by rail	General public within 80 kilometers of route – about 16 million live within 800 meters of route	~1 person rem for 10,000 railcar shipments probability of LCF 5×10^{-4}
Accidents without release	Truck or rail	One accident	Individual 30 meters from accident scene	0.0001 rem (100 μrem) probability of LCF 5×10^{-8}
			First responder	2.6 millirem probability of LCF 1.3×10^{-6}
Accidents with release, including loss of shielding accidents	Truck	0.007 for 50,000 shipments to Yucca Mountain	General public within 80 kilometers	~0.1 person-rem for 50,000 shipments probability of LCF 5×10^{-5}
	Rail	0.0008 for 10,000 shipments to Yucca Mountain	General public within 80 kilometers	~0.8 person-rem for 10,000 shipments probability of LCF 4×10^{-4}

Table 2. Dose to individuals from accidents in transporting spent nuclear fuel

Accident	Transport mode	Number or frequency	Individual or population	Dose and dose risk
Maximum reasonably foreseeable accident	Truck	~1.4 per 10^{10} cross-country truck shipments	General public within 80 kilometers in large metropolitan area	~1,000 person rem probability of LCF 0.5
			Maximally exposed individual member of the general public	3 rem probability of LCF 1.5×10^{-3}
			First responder	2.6 millirem probability of LCF 1.3×10^{-6}
	Rail	6 per 10^{10} cross-country rail shipments	General public within 80 kilometers in large metropolitan area	~10,000 person rem probability of 5 LCFs
			Maximally exposed individual member of the general public	29 rem probability of LCF 1.5×10^{-2}
			First responder	0.83 rem probability of LCF 4×10^{-4}
Traffic accident	Truck	67 per 50,000 shipments – about 3 per year if most shipments to Yucca Mountain are by truck	Member of general public or transportation worker	4.5 fatalities from causes not related to radiological characteristics of the cargo
	Rail	8 rail car accidents per 10,000 shipments – about 1 every 3 years if most shipments to Yucca Mountain are by rail		2.5 fatalities from causes not related to radiological characteristics of the cargo

Dose resulting from successful sabotage

In 1999 Sandia used advanced computational methods to estimate releases of radioactive materials from truck and rail casks that could be caused by high-energy-density (shaped charge) devices (Luna et al., 1999). To help confirm the results of the computer analysis, the researchers benchmarked the results of their computer analysis against the results of tests conducted in the late 1970's and early 1980's that used HEDDs to penetrate the shield walls of casks. The comparisons showed good agreement between experiment and computation for depth of penetration; but they also showed that computed diameters of the initial opening into a cask wall were about ½ those observed in the experiments. Given the uncertainties in the function of HEDD devices and the data used in the

computer analysis, the correlation between experiment and computation was considered to be good. Based on the comparisons, and to ensure conservatism, the researchers assumed the diameter of penetrations caused by HEDDs would be two times those estimated by computer analysis. For a truck cask, the analysis estimated that about 1% of the spent fuel contents would be destructed with about 20% of the fuel pins being damaged.

The researchers then used the computed amount of destructed and damaged spent fuel and the computed response of the cask and contents to the action of an HEDD to estimate releases of radioactive materials that could result from successful attacks. Subsequently, the analysis of the health and safety consequences of acts of sabotage that are presented in the Final EIS for the Yucca Mountain repository used Sandia's estimates of releases from a cask. These results showed that most health effects would be caused by non-respirable radioactive material ejecta if it the further assumption was that evacuation would not occur for 1 year following an event. Even with this unrealistic assumption, the analysis estimated the total dose to an urban population of 5 million could be 96,000 person-rem. If evacuation of contaminated areas occurred within 7 days, the population dose would be about 17,000 person-rem for an attack on a truck cask – less for a rail cask. Thus, assuming evacuation would not occur until 1 year after the event, the analysis estimated 48 latent fatal cancers could be caused by using an HEDD to breach a cask. Assuming evacuation occurred within 7 days, the number of latent fatal cancers would be less than 9.

The amount of damage that could be caused by an HEDD (1% of spent fuel contents) is insufficient to cause nuclear criticality to occur in a cask containing the most reactive unirradiated fuel. Even if it was possible to cause a large amount of damage, criticality could not occur in a cask containing highly irradiated spent fuel.

Summary and Conclusions

Opponents of shipments to Yucca Mountain claim that radiation from the shipments presents an unreasonable hazard to the public health. In contrast, the facts presented show that a person living 30 meters from a highway used by all truck shipments to Yucca Mountain, and who is assumed to be present when every shipment passed by, would receive a dose less than 0.05% of that from natural background radiation. For perspective, this incremental dose is more than 500 times less than the difference in the natural background radiation levels measured in Boston, Massachusetts and Denver, Colorado. The hypothetical person who received a 0.05% increment in dose above background for 24 years would have a very slightly increased probability of suffering a fatal cancer - increasing from about 23 percent from all other causes to about 23.002 percent. This small change in risk, even among a population of hypothetical maximally exposed individuals, would not be discernable.

Opponents, citing their own analysis of severe accidents, claim that these accidents can be expected to occur and will lead to disastrous economic and health consequences. To help prove its point, this opposition has circulated a list of severe transportation accidents that have occurred. In contrast, analysis performed for the US Nuclear Regulatory Commission (NRC) shows that fewer than 1 in 10,000 accidents would be severe enough to cause any release of radioactive material from a shipping cask. Using current estimates of accident rates for rail and truck transportation and accepted methods for calculating health consequences, DOE estimated the consequences of a so-called maximum reasonably foreseeable accident. The accident analyzed is very unlikely, estimated to occur about 3 times in 10 million years for shipments to Yucca Mountain. The consequences from releases of radioactive materials in this accident could be 5 latent cancer fatalities in a metropolitan population of 5 million. An accident this severe can be expected to occur somewhere on a railroad in the US once in each 20 years. Accidents that are not as severe but have dramatic, headline-grabbing effects occur more often. Based on recent analysis by the NRC, the Baltimore Tunnel fire was not as severe as DOE's maximum reasonably foreseeable accident.

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