97-403 ENR

CRS Report for Congress
Received through the CRS Web

Transportation of Spent Nuclear Fuel

Updated May 29, 1998

Mark Holt
Specialist in Energy Policy
Environment and Natural Resources Policy Division

Congressional Research Service ◻ *The Library of Congress*

ABSTRACT

The risk of transporting highly radioactive spent fuel from nuclear power plants to a central storage or disposal site is a major factor in the current nuclear waste debate. The House and Senate have passed similar bills that would establish a central nuclear waste storage site at Yucca Mountain, Nevada, which could begin receiving waste shipments within the next few years. This report discusses the adequacy of Nuclear Regulatory Commission (NRC) standards for shipping casks, the potential consequences of transportation accidents, and possible routes for nuclear waste shipments.

Transportation of Spent Nuclear Fuel

Summary

The risk of transporting highly radioactive spent fuel from nuclear power plants to a central storage site or permanent underground repository is a major factor in the current nuclear waste debate. With strong support from nuclear utilities and state utility regulators, the House and Senate have passed bills (H.R. 1270 and S. 104) that would designate a central storage site at Yucca Mountain, Nevada, that could begin receiving spent fuel shipments from nuclear plant sites as soon as possible. Environmental groups and other opponents of that plan counter that, partly because of the potential transportation hazard, spent fuel should remain stored at reactor sites until the opening of a permanent underground repository, which also is planned for Yucca Mountain. The Department of Energy (DOE) currently expects to begin operating the planned Yucca Mountain repository by 2010.

Controversy over the transportation of spent fuel and other highly radioactive nuclear waste has focused on the adequacy of Nuclear Regulatory Commission (NRC) standards for shipping casks, the potential consequences of transportation accidents, and the routes that nuclear waste shipments are likely to follow.

NRC requires that spent fuel shipping casks be able to survive a sequential series of tests that are intended to represent severe accident stresses. The tests are a 30-foot drop onto an unyielding flat surface, a shorter drop onto a vertical steel bar, engulfment by fire for 30 minutes, and, finally, immersion in three feet of water. A undamaged sample of the cask design must be able to survive submersion in the equivalent pressure of 50 feet and 200 meters of water.

Studies for NRC and other federal agencies have found that casks meeting NRC's standards would survive nearly all transportation accidents without releasing large amounts of radioactive material. The safety record of more than 1,000 past shipments of spent fuel in the United States is consistent with those findings. Four accidents occurred during those previous U.S. shipments, and none released radioactive material, according to a federal database.

NRC's cask standards and the federal safety studies have been criticized by the State of Nevada and others who contend that severe accidents could release hazardous levels of radioactivity. They argue that NRC's cask tests do not adequately represent a number of credible accident scenarios, and that individual casks may be fatally compromised by manufacturing flaws and by loading and handling errors.

Because nuclear power plants and DOE waste storage sites are located throughout the nation, almost all states are expected to be traversed by nuclear waste shipments. Major east-west highway and rail lines in the central United States are likely to be the most heavily used, but numerous options are available under current regulations. The Department of Transportation (DOT) requires that highway shipments of spent fuel follow the quickest route on the interstate highway system, although states are allowed to designate alternative routes if they follow certain procedures.

Contents

List of Figures

List of Tables

Transportation of Spent Nuclear Fuel

More than 80,000 metric tons of spent nuclear fuel, highly radioactive fuel rods that can no longer efficiently generate power, are expected to be discharged from today's nuclear power plants during their scheduled operating lives. Considered a waste material in the United States, spent fuel will remain dangerously radioactive for thousands of years. Unless spent fuel is to be kept permanently at reactor sites, it will have to be transported elsewhere for long-term storage and disposal — a prospect that has generated considerable controversy along potential transportation routes.

The Department of Energy (DOE) is required by the Nuclear Waste Policy Act of 1982 (NWPA) to study the suitability of Yucca Mountain, Nevada, for permanent underground disposal of commercial spent nuclear fuel, as well as highly radioactive waste owned by DOE. Under DOE's current schedule, disposal of nuclear waste at Yucca Mountain could begin by 2010 if the site is found suitable and receives a license from the Nuclear Regulatory Commission (NRC). That schedule, widely considered to be optimistic given the program's history, is 12 years later than the disposal deadline established by NWPA.

Nuclear utilities, state utility regulators, and other groups have been urging Congress to establish an interim storage facility at Yucca Mountain to begin receiving nuclear waste much sooner than currently planned by DOE. The House and Senate have passed similar bills (H.R. 1270 and S. 104) that would establish tight schedules for transporting nuclear waste to a Yucca Mountain storage facility. (For details, see CRS Issue Brief 92059, Civilian Nuclear Waste Disposal.)

The interim storage bills are vehemently opposed by the State of Nevada, environmental groups, and other organizations that cite transportation hazards as one of their primary concerns. The opponents of central storage contend that, because NRC has determined on-site storage to be adequately safe, any risk posed by transporting spent fuel from reactor sites in the near term is unnecessary. Nuclear utilities, noting that NRC also has found transportation to be adequately safe, respond that the benefits of central storage of spent fuel far outweigh any transportation risks involved.

Although it is generally expected that spent fuel will be transported from nuclear power plants eventually, opponents of the Yucca Mountain interim storage plan point out that extended on-site storage would allow for radioactive decay in spent fuel before it was shipped. After 100 years, radioactivity in spent fuel would drop by more than 99 percent, although it still would contain more than 10,000 curies per metric ton,[1] and long-lived radioactive elements such as plutonium would not have decayed significantly.

Major issues in the transportation debate are the extent of the risks posed by a national shipping campaign for spent fuel, the adequacy of federal regulation of transportation safety, and the possible concentration of shipments along certain major east-west transportation routes. This report discusses currently available statistics, analyses, and other studies that may be used to evaluate those concerns.

Nuclear Waste Transportation Accident Risks

Risks to the public posed by transporting spent nuclear fuel depend on the rate of transportation accidents and the likely consequences of such accidents. The annual accident rate will depend primarily on the amount of spent fuel shipped by truck and the amount shipped by rail, which have differing numbers of accidents per mile. Consequences depend on the severity of the accidents that occur, including such factors as vehicle speed and the presence of fire.

Opponents of spent fuel transportation have compared the amount of long-lived radioactive material in a large transportation cask to 200 Hiroshima atomic bombs,[2] but federal studies have found few credible mechanisms that would release more than a small fraction of a cask's contents. It is also impossible for spent fuel to explode like a nuclear bomb, which releases a powerful blast, intense heat, and a burst of penetrating radiation that causes much more damage than the concurrent dispersal of the bomb's radioactive material.

NRC regulations are intended to ensure that spent fuel transportation casks can survive all but the most severe accidents with minimal releases of radioactive material. Nuclear industry critics and others contend that NRC's cask standards are inadequate for many plausible accidents, such as high-speed collisions with concrete bridge supports and long-duration fires fueled by broken oil pipelines.

Transportation Cask Standards

For a cask design to receive an NRC license, it must be demonstrated to NRC's satisfaction that the cask could survive a sequential series of tests that are intended to simulate the stresses of a severe accident (10 CFR 71.73). The tests are a 30-foot drop onto an unyielding surface, a shorter drop onto a vertical steel bar, engulfment by fire for 30 minutes, and, finally, immersion in three feet of water. A separate, undamaged sample of the cask design must be able to survive submersion in the

---

[1] U.S. Department of Energy. Integrated Data Base for 1993: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics. DOE/RW-0006, Rev. 9. March 1994. P. 21.

[2] Nuclear Monitor. No More Chernobyls. Nuclear Information & Resource Service. March 1996. P. 6.

equivalent pressure of 50 feet of water. Furthermore, the cask must not leak for one hour under 200 meters of water (10 CFR 71.61).

To be judged successful in meeting those tests (except the 200 meter submersion), a cask must be found to release no more than a specified amount of each radioactive isotope in spent fuel in one week, and it must not emit radiation at a dose rate of greater than 1 rem per hour at a distance of 1 meter from the cask surface (10 CFR 71.51). In addition, the tests must not allow spent fuel in the cask to undergo a nuclear chain reaction, or criticality (10 CFR 71.55). A 1987 analysis conducted by Lawrence Livermore National Laboratory for NRC found that a cask meeting those standards would survive about 99.4% of truck and rail accidents with minimal damage.[3]

A cask's ability to survive those tests can be demonstrated in several ways (10 CFR 71.41). First, an actual, full-sized model of the cask can be subjected to all the tests in the sequence. Alternatively, the tests can be applied to small models of the casks (typically half- or quarter-scale). Finally, casks may be compared to previous licensed designs or analyzed with computer models. NRC decides what level of physical testing or analysis is necessary for each cask design.

Because NRC generally accepts the results of scale-model testing, expensive full-scale testing of entire spent fuel casks is rarely conducted, although such tests are sometimes required for specific cask components. For example, NRC may require quarter-scale drop tests for a particular cask design but require full-scale tests of the cask's impact limiters (cushioning material typically attached to each end). Computer analysis may be allowed for meeting the fire test and for criticality control. Various environmental and other groups have urged DOE to conduct full-scale testing on any cask designs to be used for Yucca Mountain shipments. DOE currently has committed to verifying its cask designs at least with scale-model testing, according to NRC.[4]

Thirty-Foot Drop. The first test in the hypothetical accident series requires the sample cask to be dropped 30 feet onto a "flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected." At that height, the cask strikes the surface at a speed of 30 miles per hour (mph).[5] Striking an unyielding surface at 30 mph, when all the impact energy is absorbed by the cask, is approximately equivalent to a 60 mph impact with a "medium" surface, such as shale and other relatively soft rock, and a 90 mph impact with a "soft" surface, such as tillable soil.[6]

---

[3] Fischer, Larry E., et al. Shipping Container Response to Severe Highway and Railway Accident Conditions. Prepared for NRC by Lawrence Livermore National Laboratory. NUREG/CR-4289, UCID-20733, Vol. 1. P. 7-25.

[4] Telephone conversation with Earl Easton, Nuclear Regulatory Commission. January 29, 1997.

[5] Fischer, op. Cit. P. 1-10.

[6] Fischer, L.E. op. Cit. P. 4-8.

Accidents that might exceed those stress levels include high-speed collisions with massive concrete bridge abutments and falls from high bridges onto hard rocks or other very hard surfaces. The NRC drop test has also been criticized for using a flat surface, which allows a fall to be cushioned by crushable "impact limiters" typically bolted to each end. It has been pointed out that the impact limiters might be useless if the side of a cask struck an irregular surface,[7] such as the corner of a bridge abutment or a concrete pillar.

Puncture Test. After being dropped 30 feet, the cask specimen must be dropped 1 meter onto the end of a vertical bar mounted on an unyielding horizontal surface. The vertical bar must be made of mild steel, 6 inches in diameter, and at least 8 inches long. At that height, the cask would strike the end of the steel bar at 10 mph. The test is intended to simulate the fall of a cask from a trailer or rail car onto a railroad track after a crash.[8]

Because the entire weight of the heavy transportation cask is focused on the steel bar, a total force of about 6 million pounds is generated. The mild steel bar will fail at about 2 million pounds of force. However, critics have argued that nuclear waste shipping casks might be strike potentially puncturing objects with greater force in actual accidents.[9]

Engulfing Fire. The crash and puncture tests are followed by a 1,475-degree-Fahrenheit fire that must engulf the test cask for 30 minutes. After the 30-minute period, any combustion of cask materials must be allowed to continue until stopping by itself, and no artificial cooling is permitted.

Major variables in determining the total thermal effect on a cask are flame temperature, flame distance from the cask, fire duration, and the percentage of the cask surface that is surrounded by flames. According to the Lawrence Livermore report, the 1,475-degree hypothetical engulfing fire required by NRC regulations is equivalent to a real engulfing fire of 1,700 degrees F, because of the shielding effects of the transport vehicle, ground, or whatever else the cask might be resting on. In the NRC test fire, the cask must be suspended in the engulfing fire by test supports that minimize interference with heat transfer.

NRC's fire test has been criticized for specifying a flame temperature below that of many motor fuel fires. For example, a gasoline tanker fire can reach 1,900 degrees F.[10] However, the Lawrence Livermore report concluded that few actual fires would exceed the combination of factors — temperature, duration, flame distance, and degree of engulfement — required by the NRC hypothetical fire requirements.

---

[7] English, Gordon. Railroad Transport of Spent Nuclear Fuel (A Risk Review). TranSys Research Ltd., for the Association of American Railroads. P. iii.

[8] Audin, Lindsay. Nuclear Waste Shipping Container Response to Sever Accident Conditions: A Brief Critique of the Modal Study. Prepared for Nevada Nuclear Waste Project Office. NWPO-TN-005-90. P. 20.

[9] English, op. Cit. P. iii.

[10] Fischer, op. Cit. P. 9-16.

Immersion in Water. Because water could reduce the effectiveness of some cask features designed to prevent a nuclear chain reaction (criticality), the test cask must next be immersed under three feet of water. An undamaged version of the test cask, as noted above, must also be able to survive immersion in the equivalent of 50 feet of water (about 22 pounds per square inch) to test for leakage. Neither of those tests is required if the license applicant has already conducted a criticality analysis that assumes water leakage.

Shipping casks holding more than 1 million curies of radioactivity (expected to include virtually all spent fuel casks) must be able to survive water pressure of 290 pounds per square inch for one hour without deformation or leakage (10 CFR 71.61). That pressure is equivalent to a depth of about 200 meters; the standard is intended to ensure that casks sunk on the outer continental shelf could be retrieved with their contents intact.

Studies of Transportation Accident Risk

Federally funded studies of nuclear waste transportation accident risks have concluded that current regulations provide an adequate margin of safety. The 1987 Lawrence Livermore study for NRC contains widely cited calculations of potential nuclear waste transportation accident rates and severity. Often referred to as the "Modal Study," the Livermore report analyzed truck and rail accident rates and modeled the stresses that each type of accident would pose to hypothetical NRC-licensed transportation casks. The study concluded that extremely few accidents would pose a significant radiation hazard to the public, concurring with a previous NRC regulatory evaluations that "indicate that the expected radiological consequences from the shipment of 3000 metric tons of spent fuel per year is less than 1 latent cancer fatality every 2300 years."[11]

The Livermore study was criticized by a consultant to the State of Nevada in a 1990 report, which concluded that "the Modal Study is a good start, but it is too simplistic, incomplete, outdated and open to serious question to be used as the basis for any present-day environmental or risk assessment of spent fuel transportation."[12] Some of those criticisms were addressed by a 1995 Lawrence Livermore study that used improved computer modeling of accident effects on a new truck cask design.[13] The latest study concluded that accident effects on the new truck cask would be comparable to or less severe than the effects predicted for a truck cask in the earlier Modal Study.

Accident Probabilities. The Livermore Modal Study relied on a variety of accident data to develop accident rates for trains and trucks, a distribution of accident speeds, and a distribution of types of accidents. For trucks, the study calculated an

---

[11] Fischer, op. Cit. P. 9-29.

[12] Audin, op. Cit. P. 1.

[13] O'Connell, W.J., et al. Transportation Accident Response of a High-Capacity Truck Cask for Spent Fuel. Lawrence Livermore National Laboratory. UCRL-JC-123421. November 1995.

accident rate of about six for each million miles traveled, and that 95% of accidents involved speeds of 50 mph or less. Trains were estimated to suffer about 12 accidents per million miles, with more than 95% occurring at less than 50 mph.[14]

Truck and train accidents were divided into numerous scenarios, and the probability of each accident scenario was calculated from historical accident statistics and other data. For example, 0.4% of truck accidents were included in a scenario in which a truck collided with a bridge railing and landed on a road or railbed. The most common single scenario for trucks was collisions with automobiles, which accounted for 43% of all truck accidents. About 10% of truck accidents involved collisions with walls and other stationary objects, and about 25% of truck accidents were classified in "non-collision" scenarios, such as jackknifings. Derailment scenarios accounted for more than 80% of train accidents, with a small percentage of derailments caused by collisions.

For each accident scenario, the Modal Study calculated the probability of relevant variables, such as cask velocity, the presence of fire, and cask impact angle and orientation. Velocity is primarily determined by vehicle speed and, in the case of falls, bridge and overpass heights. Fire effects depend on frequency, duration, temperature, and location. Probabilities for each of those variables were developed from available data, such as bridge heights, or calculated by formulas.

The Modal Study's accident probabilities were criticized by the 1990 Nevada report for relying on potentially incomplete accident data. It was pointed out that accidents in the American Petroleum Institute data base, from which the Modal Study derived its truck accident rate, are reported voluntarily from member companies. The Nevada report also noted that Federal Railroad Administration accident data used by the Modal Study had been criticized by the General Accounting Office. The Modal Study's primary reliance on statistical techniques in determining the probability of each accident scenario creates additional uncertainty about the study's conclusions, according to the Nevada critique.[15]

Potential Accident Consequences. To determine the possible consequences of nuclear waste transportation accidents, the authors of the Livermore Modal Study developed computer models of hypothetical truck and rail casks that were intended to meet NRC requirements with a minimally acceptable margin of safety.[16] Computer simulations were then conducted to estimate the effects of heat and impact on the hypothetical casks.

Impact effects were measured by the level of strain (stretching) on a transportation cask's inner wall. Fire effects were measured by the temperature at the center of a cask's lead shielding. For each potentially significant accident scenario (including cask velocity, fire duration, and the other variables noted above), the

---

[14] Fischer, op. Cit. Appendices B and C.

[15] Audin, op. Cit. P. 13.

[16] Fischer, op. Cit. P. 3-23.

Modal Study determined the probability that strain and temperature would fall into each of the following levels:

- *Strain Level 1.* Strain on the cask's inner wall does not exceed 0.2%. That is the maximum elastic strain that the stainless steel in the hypothetical casks can withstand; at that level, a cask's inner wall would regain its shape with essentially no damage.
- *Strain Level 2.* Strain on the cask's inner wall is between 0.2% and 2%. Stainless steel does not regain its shape, and seal deformation may allow small releases of radioactive material. Lead shielding may shift and open small gaps for the emission of gamma rays. Radiological hazards are expected to remain within the NRC accident limits described above.
- *Strain Level 3.* Inner-wall strain is between 2% and 30%, which can cause large, permanent distortions of the stainless steel and cracking of welded areas. Large cask distortions would probably break seals and shift the lead shielding. Resulting radiological hazards may exceed the NRC accident limits.
- *Temperature Level 1.* Temperature in the middle of the lead shielding does not exceed 500 degrees F. Lead shielding and cask seals are not damaged, although water in the outer neutron shield is lost.
- *Temperature Level 2.* Lead mid-thickness temperature reaches between 500 and 600 degrees F. Lead does not melt, but seals may degrade and release amounts of radioactive material below the NRC accident limits.
- *Temperature Level 3.* Lead mid-thickness temperature reaches between 600 and 650 degrees F. Lead shielding melts, increases in volume, and strains the inner canister. Gaps may open in lead shielding, and cask seals are assumed to leak. Radiological hazard is likely to exceed NRC accident limits.
- *Temperature Level 4.* Mid-thickness temperature of the lead shielding reaches between 650 and 1,050 degrees F. The lead shielding is further degraded, and fuel rods may burst.

For each potential combination of strain and temperature levels, an amount of likely radiological release and radiation exposure was calculated. For example, if an accident resulted in strain at level three and temperature at level two in the hypothetical rail cask, the study calculated that 21,000 curies of noble gases, 300 curies of vaporized radioactive material, and 0.15 curie of radioactive particles would be released, and the degraded lead shielding would allow gamma ray emissions equivalent to 110 curies.

After the likely impact and fire damage levels had been determined for each scenario, the probabilities of all the scenarios could be combined to determine the percentage of all accidents that would cause each level of damage. The Modal Study calculated that about 99.4% of all truck and rail nuclear waste accidents would fall into the first level of strain and temperature, resulting in little or no radiological hazard. Approximately 0.4% percent additional accidents would be expected to reach no higher than level two in either strain or temperature, causing a radiological hazard within NRC limits. About 0.2% would be level three or above, with potentially more severe consequences, according to the study.[17]

Four of the most severe historical transportation accidents were analyzed by the study to determine the damage levels that might have been incurred by spent fuel shipping casks:[18]

- A 1982 gasoline tanker truck fire in the Caldecott Tunnel near Oakland, California, which was estimated to have produced a peak flame temperature of 1,900 degrees F. for about 40 minutes. If a nuclear waste cask had been engulfed by the fire, the study concluded, the lead shielding would have remained within temperature level one.

- A 1981 accident in which a tractor trailer fell 64 feet from an Interstate 80 overpass near San Francisco and struck the ground at an estimated speed of 44 mph. The study calculated that such an impact would have been close to exceeding strain level one.

- A 1982 train derailment near Livingston, Louisiana, after which various petroleum products burned for several days and two explosions occurred. If a nuclear waste cask had been among the burning rail cars, the temperature would have reached level four, exceeding NRC accident release limits, according to the study.

- A 1979 train derailment off a bridge into the Alabama River near Hunter, Alabama. Five cars fell 75 feet into the muddy riverbed at an estimated velocity of 47 mph, well within strain level one, the study estimated.

A series of British studies during the 1980s studied real accident parameters and reached similar conclusions:

> The results of the studies showed that, although severe transport accidents are possible, the mitigating factors associated with the strength of real targets, the energy absorbing characteristics of railway and other vehicle structures and the precise mechanics of any real accident all serve to considerably reduce the damage potential of the accident from its apparent face value.[19]

On the other hand, the 1990 Nevada report contended that the Modal Study's conclusions may have significantly underestimated the potential consequences of

---

[17] Fischer, op. Cit. P. 7-25, 7-26.

[18] Fischer, op. Cit. P. 9-15.

[19] Blythe, R.A., et al. The Central Electricity Generating Board Flask Test Project. Packaging and Transportation of Radioactive Materials, PATRAM '86, Vol. 2. International Atomic Energy Agency. 1987. P. 440.

nuclear waste transportation accidents. A major criticism was that the Modal Study neglected the effects of human error in cask construction and handling, such as the potential failure of workers to properly attach impact-cushioning end caps (impact limiters) to a cask before a shipment.[20] A 1978 study by DOE's Pacific Northwest Laboratory of nearly 4,000 spent fuel shipments found that cask construction and handling errors had occurred in 16 cases. Those errors included a cask shipped with improperly installed impact limiters, improperly closed or missing bolts on six casks, open vent valves on two casks, and a leaking closure seal.[21]

Criticizing the Modal Study's analysis of cask damage that might have been caused by severe historical accidents, the Nevada report noted that worse transportation accidents had since occurred, such as a leaking natural gas pipeline that was ignited by a train in the former Soviet Union. The Nevada report also contended that the Modal Study's computer simulations did not account for some potentially severe stresses on transportation casks during accidents, and that spent fuel in the casks was likely to suffer greater damage than projected.[22] For example, the Nevada report alleged that the Modal Study inadequately considered the potential effects of air entering a cask during a fire, which at temperatures above 400 degrees F. could result in "breaking ceramic fuel pellets down into an aerosol powder."[23] The Modal Study calculated that such chemical oxidation could cause releases of radioactive gases and vapors, but not particles.[24]

Lawrence Livermore National Laboratory released a follow-up to the Modal Study in 1995 that addressed some of the concerns raised by the Nevada report. Rather than analyzing hypothetical casks, the 1995 Livermore study examined the GA-4 truck cask developed by General Atomics. Additional impact stresses were modeled, such as "slap down," when a cask falls on a flat surface at a slight angle, and side impact by the center of the cask against a column or hard corner. Thermal effects were also analyzed, including those of a 1,900 degree F. engulfing fire for up to four hours. The GA-4 cask was found to perform as well as or better than the hypothetical casks in the Modal Study, leading the authors of the 1995 study to conclude that "the analysis methods used in the Modal Study nine years ago were reasonable."[25]

Crash Tests. Catastrophic truck and rail accidents have been staged by U.S. and British laboratories to study the response of full-scale spent fuel casks. Those tests, which were designed primarily to verify computer models, yielded spectacular films and photographs that have been widely cited as strong evidence of nuclear waste transportation safety, because the casks survived without releasing their

---

[20] Audin, op. Cit. P. 14.

[21] Shapiro, Fred C. Radwaste: A Reporter's Investigation of a Growing Nuclear Menace. Random House. 1981. P. 211.

[22] Audin, op. Cit. P. 3.

[23] Audin, op. Cit. P. 32.

[24] Fischer, op. Cit. P. 8-13.

[25] O'Connel, op. Cit. P. 8.

contents. However, critics have downplayed the significance of the crash tests in demonstrating transportation safety.

Sandia National Laboratories conducted four crash tests of U.S. spent fuel casks during 1977 and 1978. In the first test, a truck carrying a 22 ton cask was crashed into an essentially unyielding wall at 60 mph, causing very little damage to the cask. The same cask was then loaded onto another truck and driven into the wall at 84 mph, again causing minor cask damage. In the third test, a locomotive traveling at 81 mph struck a 25 ton cask on a truck trailer that was parked across the tracks. The fourth test involved crashing a rail car carrying a 74 ton spent fuel cask into the unyielding wall, and the same cask and rail car were then engulfed in a jet-fuel fire for 90 minutes. According to Sandia, none of the tests would have released hazardous levels of radioactivity, had the casks held actual spent fuel.[26]

Critics of the Sandia tests have cited a number of reasons why the apparently good results should not be taken at face value. A report by the State of Nevada described Sandia's films of the tests as "propaganda."[27] The primary criticisms of the tests include:

- One crash test released about half a cup of cooling water, and the fire test vented steam into the environment. In a cask containing spent fuel, radioactive material might have escaped with the water and steam.
- Shortly after the fire test, the outer cask shell cracked and some of the lead shielding (which had melted) was lost.
- The casks tested were obsolete, so the results might not be applicable to current models.
- The lack of real spent fuel in the test casks eliminated a major internal heat source that could affect the results, particularly of the fire test.
- The test crashes did not represent the most severe range of plausible accident scenarios, such as direct cask collisions with solid or irregular structures. In the head-on collisions with the unyielding flat wall, the truck cab absorbed most of the energy. Similarly, the main structural members of the locomotive did not strike the sideways cask at the center of gravity, where maximum force might be generated.

Sandia researchers have generally characterized such concerns as having relatively little significance. For example, one Sandia official estimated that the heat from spent fuel would have reduced the melting time of a cask's lead shielding by

---

[26] Sandia National Laboratories. Five Full Scale Crash Tests — 1977. Undated videotape.

[27] Audin, Lindsay. Nuclear Cask Testing Films Misleading and Misused. State of Nevada Agency for Nuclear Projects/Nuclear Waste Project Office. NWPO-TN-012-91. October 1991. P. 20.

only about five minutes.[28] It has also been asserted that the damage-mitigation factors in the crash tests, such as energy absorption by the truck cab, would be expected in the vast majority of real accidents.

The British train crash demonstration, conducted in 1984, involved a locomotive weighing 140 metric tons pulling three 33-metric-ton passenger cars at 100 miles per hour. The train struck a British Magnox spent fuel cask weighing 48 metric tons that had been placed on the tracks in what was believed to be its most vulnerable position. The cask held three metric tons of steel bars meant to simulate spent fuel. According to a report on the demonstration, the cask was positioned "so that a valve would be in the impact zone and so that the wheels and tow-hook on the locomotive would inflict maximum damage to the lid bolts."[29]

Extensive monitoring of the demonstration indicated that almost no cask pressure had been lost and that no radioactivity would have been released by the crash. Measurements showed that the train impact was substantially less severe than the impact of the 30-foot drop test onto an unyielding surface. A report on the demonstration concluded that computer models could predict crash forces on spent fuel casks "with a high degree of confidence."[30]

However, the relevance of the British test to the substantially different U.S. cask designs has been called into question by some critics. The Nevada critique of the Modal Study noted that the British cask "was a solid forged design, not the welded steel and lead sandwich simulated in the Modal Study."[31]

Potential Number of Waste Transportation Accidents. The Modal Study's probability calculations can be applied to the anticipated number of miles that all truck and rail casks would travel in transporting nuclear waste to Yucca Mountain. A 1996 study for the State of Nevada estimated that shipping 86,000 metric tons of nuclear waste to the site, the total expected from all currently and previously operating U.S. reactors, would require up to 76 million cask shipment miles over 30 years, assuming minimal rail use and small truck casks. In a mid-range case, which assumes moderate rail use, the Nevada study estimates that cask shipment miles would total 15.3 million for trains and 24.1 million for trucks.[32]

Multiplying the Modal Study's truck accident rate of 6.4 per million miles by the 24.1 million truck-cask miles projected by the Nevada study yields a total of 154.2 truck accidents over 30 years. If 99.4% of those accidents were within level

---

[28] Shapiro, Fred C. Radwaste: A Reporter's Investigation of a Growing Nuclear Menace. Random House. 1981. P. 215.

[29] Blythe, op. Cit. P. 441.

[30] Ibid. P. 442.

[31] Audin, op. Cit. P. 24.

[32] Planning Information Corporation. The Transportation of Spent Nuclear Fuel and High-Level Waste: A Systematic Basis for Planning and Management at National, Regional, and Community Levels. Prepared for Nevada Nuclear Waste Project Office. September 10, 1996. P. 104.

one of strain and temperature, 153.4 of those accidents would result in little or no radiological hazard. An average of 0.6 truck accidents would reach no higher than level two, and an average of 0.3 accidents would reach level three or higher.

For rail shipments, the Modal Study estimated an accident rate of 12 for every million miles traveled per train. If each nuclear waste train were assumed to carry 10 waste casks, the 15.3 million rail cask miles from the Nevada study would translate into 1.5 million shipment miles. Multiplying that number by the accident rate produces an estimate of 18.4 accidents over 30 years. If 99.4% were level-one accidents, 18.3 of those accidents would create little or no radiological hazard. An average of 0.07 rail accidents would reach level two, and an average of 0.04 accidents would be more severe.

Table 1. Projected Nuclear Waste Transportation Accidents for 30 Years

	Truck	Rail
Accident rate per million shipment miles	6.4	12
Total shipment miles	24.1 million	1.5 million
Total accidents	154.2	18.4
Level 1 accidents	153.4	18.3
Level 2 accidents	0.6	0.07
Level 3 and higher	0.3	0.03
Total number of shipments	26,093	1,392*
Average shipments per accident	169.2	75.8

* Assumes 10 casks per rail shipment

Source: Accident rates and severity levels from Lawrence Livermore National Laboratory. Cask shipment miles and number of shipments from Nevada Nuclear Waste Project Office. Total accident estimates calculated by CRS.

History of Spent Fuel Shipments

Although the vast majority of U.S. spent fuel has never been moved from the reactors that generated it, numerous shipments have taken place. Utilities have transported spent fuel among reactor sites for storage, and some has been shipped to commercial reprocessing and storage facilities. During the 1980s, spent fuel debris from the ruined Three Mile Island 2 reactor was shipped to the Idaho National Engineering Laboratory. DOE also has transported significant amounts of spent fuel from naval and research reactors. No known radiological harm to the public has resulted from those shipments, according to NRC:

> The safety record for spent fuel shipments in the U.S. and in other industrialized nations is enviable. Of the thousands of shipments completed over the last 30 years, none has resulted in an identifiable injury through release of radioactive material.[33]

NRC statistics show that 1,335 metric tons of spent fuel was commercially transported in the United States from 1979 through 1995, in 1,306 separate shipments. A total of 356 metric tons were transported in 1,168 highway shipments, while 979 metric tons were carried in 138 rail shipments. The highest amount commercially transported in one year was 193.4 metric tons in 1985. During that period, the distance traveled by all commercial nuclear waste shipments totaled 839,000 miles.[34]

According to statistics compiled from NRC-licensed waste transporters, eight transportation accidents involving spent fuel casks occurred from 1971 through 1995, none of which released radioactive material. That accident rate appears to be generally consistent with the probabilities discussed in the previous section. In four of those accidents, the spent fuels casks being transported were empty and were undamaged. The other four accidents involved loaded casks:[35]

- A December 1971 accident, in which a truck left the road and threw off its spent fuel cask, which suffered some damage;

- An incident in February 1978, in which a truck trailer carrying a spent fuel cask buckled under the weight, but the cask was undamaged;

- A December 1983 accident, when a spent-fuel truck tractor separated from its axles, without damaging the cask; and

- An accident in March 1987, when a train carrying two casks of Three Mile Island core debris collided with a car, causing no cask damage.

Foreign experience with spent fuel transportation has been similar. In more than 7,000 rail shipments of spent fuel in Britain through 1986, “there have been no accidents involving a release of radioactivity,” according to a report by the Central Electricity Generating Board.[36]

Critics of DOE’s nuclear waste transportation plans, such as the State of Nevada, contend that the historically good safety record for spent fuel shipments is too short to be a reliable indicator of future safety. All the U.S. commercial spent fuel shipped from 1971 to 1995 is only a small fraction of the 86,000 metric tons that

---

[33] U.S. Nuclear Regulatory Commission. Public Information Circular for Shipments of Irradiated Reactor Fuel. NUREG-0725, Rev. 11. July 1996. P. 2.

[34] Ibid. P. 8, 12.

[35] U.S. Nuclear Regulatory Commission. Transportation Incident Summary Report 1971-1995. P. 6.

[36] Blythe, op. Cit. P. 433.

may eventually require transportation to a central storage site or repository. Over 30 years, such shipments would average nearly 3,000 metric tons per year, far higher than any previous U.S. annual total. The number of cask shipment miles would total at least 20 times the current total, according to the Nevada mileage estimate noted previously.

Emergency Response

When a nuclear waste transportation accident occurs, local emergency personnel are normally the first authorities on the scene. Their ability to take appropriate action, such as extinguishing fires and organizing evacuations, can be an important factor in mitigating an accident's consequences. Such state and local capability depends largely on adequate training and preparation.

Section 180(c) of the Nuclear Waste Policy Act requires DOE to provide technical assistance and funding to states for training public safety officials of units of local government along transportation routes for high-level waste and spent fuel. The training is to cover routine shipments as well as response to transportation emergencies. Funding for the assistance program is to be provided from the Nuclear Waste Fund, which contains fees assessed on nuclear power generation.

DOE issued a policy proposal May 16, 1996, for implementing the technical assistance program (61 FR 24772). A local jurisdiction would be eligible for the grants beginning 3 years before nuclear waste shipments were to begin traversing it; eligibility would continue for each year that the route through the jurisdiction was to be used. Under the proposal, funding could be used for training new emergency personnel, refresher courses, and related equipment. Additional drills and exercises would be conducted by DOE in conjunction with states, Indian tribes, and local governments.

Under current law, nuclear waste shipments to Yucca Mountain are not expected to begin for at least another decade, giving DOE several years to select routes and prepare for local emergency response training. However, legislation such as S. 104 would require waste transportation to a Yucca Mountain interim storage facility to begin much sooner, raising questions about the readiness of local emergency officials. Options for ensuring emergency readiness for early waste transportation include increasing DOE's planned technical assistance grants so that emergency training could be completed more quickly, and sending trained emergency personnel along with each shipment until local personnel were ready.[37]

The Department of Transportation provides annual grants to states, Indian tribes, and localities for emergency response planning and training for hazardous materials transportation accidents. Those grants, although not aimed specifically at shipments of highly radioactive material, would be expected to increase the general emergency

---

[37] Telephone conversation with Maria J. Booth, DOE Office of Civilian Radioactive Waste Management, Office of Waste Acceptance, Storage, and Transportation. March 21, 1997.

response capabilities of local officials. DOT awarded $8 million in grants to all states and territories in FY1994.[38]

Threat of Sabotage

Sabotage of nuclear waste transportation casks could potentially release more radioactive material than accidents. Although no such act has ever occurred in the United States, "there has been at least one case of attempted sabotage of a rail shipment," according to a report for the State of Nevada.[39] A wide variety of armor-piercing weapons could penetrate the heavy steel transportation casks, pulverize some of the nuclear waste inside, and allow highly radioactive waste particles to escape into the environment. However, studies conducted for NRC have found that such releases, while potentially hazardous, would probably not exceed a small fraction of a cask's contents.

Studies of Potential Sabotage Hazard

Studies of potential sabotage damage to nuclear waste transportation casks were conducted during the 1980s by Sandia National Laboratories and Battelle Columbus Laboratories.[40] In those studies, armor-penetrating explosive devices were fired directly at a variety of full- and partial-scale casks containing real and simulated spent nuclear fuel. The explosions breached the test casks and damaged some of the nuclear material inside, but far less radioactivity escaped than had previously been estimated.[41]

Battelle and Sandia researchers selected an M-3 conical shaped charge as the most hazardous weapon that saboteurs would be likely to deploy against nuclear waste transportation casks. Such a shaped charge consists of high explosives surrounding a conical cavity lined with metal, such as copper or iron. Upon detonation, the high explosive collapses the metal-lined cavity and ejects the metal in an extremely high-velocity jet with great penetrating power.

---

[38] U.S. Department of Energy. OCRWM Transportation Report. DOE/RW-0473. June 1995. P. 20.

[39] Nevada Agency for Nuclear Projects/Nuclear Waste Project Office. A Report on High-Level Nuclear Waste Transportation. December 1988; reprinted 1991. P. 44.

[40] Miller, N.E, et al., Battelle's Columbus Division. Radiological Source Terms Resulting From Sabotage to Transportation Casks. Prepared for U.S. Nuclear Regulatory Commission. NUREG/CR-4447, BMI-2131. November 1986.

Sandoval, R.P., et al., Sandia National Laboratories. An Assessment of the Safety of Spent Fuel Transportation in Urban Environs. SAND82-2365. June 1983.

Schmidt, E.W., et al., Battelle Columbus Laboratories. Final Report on Shipping Cask Sabotage Source Term Investigation. Prepared for U.S. Nuclear Regulatory Commission. NUREG/CR-2472, BMI-2095. October 1982.

[41] Sandoval, op. Cit. P. 4.

The M-3 is a relatively low-precision shaped charge designed primarily for penetrating concrete structures, and is one of the largest shaped charges in the U.S. inventory. It will penetrate 20 inches of armor steel and 30 inches of mild steel, and makes an entrance hole averaging nearly 4 inches in diameter.[42] It carries a greater mass of high explosives than anti-tank systems cited by Jane's Infantry Weapons,[43] and makes a wider hole than high-precision shaped charges. Although there may be weapons and other explosive devices that could make a larger hole in a transportation cask, the M-3 is considered by Battelle and Sandia researchers to be a valid indicator of the potential threat.

In the Battelle and Sandia experiments, the metal jet produced by each shaped charge produced an entrance hole and, usually, an exit hole in the casks. (A full-scale cask test at Sandia produced an entrance hole about 6 inches in diameter and no exit penetration.) The real or simulated spent fuel in the path of the metal jet was pulverized, but cask contents not directly hit by the jet suffered little or no damage. Unlike tanks and other typical targets of armor-piercing weapons, nuclear waste casks contain no explosive or combustible materials that could be touched off by the shaped-charge jets, so little secondary damage occurred in the tests.

The Sandia researchers calculated from the experimental data that an attack on a truck cask carrying three spent fuel assemblies would release a maximum of 34 grams of respirable irradiated fuel. If the attack took place in a densely populated urban area, such a release could cause as many as 14 latent cancer fatalities, the report concluded.[44] Larger truck or rail casks, holding substantially more spent fuel, might release greater quantities of radioactive material, depending on the penetration and diameter of the shaped-charge jet.

Physical Protection Regulations

NRC physical protection regulations for spent fuel transportation (10 CFR 73.37), which DOE follows,[45] are designed to reduce the risk of sabotage. NRC-licensed shippers must establish methods for early detection of attempts to attack or steal spent fuel shipments, develop procedures for alerting police and other sabotage response forces, and impede would-be saboteurs or thieves until reinforcements can arrive.

NRC requires its licensees to notify NRC in advance of each shipment of more than 100 grams of highly radioactive spent fuel, and such shipments must be regularly monitored by a licensee-operated communications center. Highway

---

[42] Vigil, Manuel G., and Sandoval, Robert P. Development of a Method for Selection of Scaled Conical Shaped Explosive Charges. Sandia National Laboratories. SAND80-1770. March 1982. P. 2.

[43] Gander, Terry J., and Hogg, Ian V. Jane's Infantry Weapons, 1995-96. Jane's Information Group. 1995.

[44] Sandoval, op. Cit. P. 4.

[45] Telephone conversation with William C. Floyd, DOE Office of Civilian Radioactive Waste Management, September 25, 1996.

shipments must be accompanied by at least one armed escort in heavily populated areas, and rail shipments must be accompanied by at least two. In lower-population areas, all shipments must have at least one unarmed escort. Licensees must also arrange for emergency response by local law enforcement agencies along planned transportation routes and meet other general requirements.

Spent-fuel shippers are required by NRC regulations (10 CFR 71, 10 CFR 73) to provide at least four days' notice to the governor of any state through which such a shipment will pass. DOE is developing a satellite tracking system that may be used to notify states of the status of spent-fuel shipments. Some states require that state law enforcement agencies provide continuous escorts and aerial surveillance of nuclear waste shipments.[46]

Congress established specific penalties in 1995 for sabotaging a train or motor vehicle carrying spent nuclear fuel or high-level waste (P.L. 104-88, Section 402). Previously, the maximum prison sentence for willful destruction, tampering, or other sabotage of a motor vehicle or train used in interstate commerce was 20 years. The 1995 provisions established a minimum 30-year prison sentence for any such sabotage involving radioactive waste, with a maximum of life imprisonment.

Transportation Routing

Several studies have examined potential transportation routes to the Yucca Mountain site, on the assumption that high-level waste and spent fuel will eventually be shipped there for storage, disposal, or both. Because nuclear power plants and DOE waste storage sites are located throughout the nation, almost all states are expected to be traversed by nuclear waste shipments. Major east-west highway and rail lines in the central United States are likely to be the most heavily used, but numerous options are available under current regulations.

Federal Routing Regulations

Highway routing of spent fuel shipments is regulated by the Department of Transportation (DOT) under the Hazardous Materials Transportation Act (P.L. 93-633). DOT's highway routing regulations (49 CFR 397.101 and 49 CFR 397.103), commonly referred to by their docket number of HM-164, require trucks transporting spent fuel to stay on federal interstate highways or on alternative routes properly designated by states or Indian tribes. The HM-164 regulations preempt any conflicting routing requirements issued by state or local governments, such as prohibitions on radioactive waste shipments through local "nuclear-free zones."

Spent-fuel truck shipments can leave the interstate highway system or state-designated alternative routes only in specified situations, such as during pickup of spent fuel from nuclear power plants, which are typically not located along major highways. During pickups and deliveries, trucks generally must choose the most

---

[46] U.S. Department of Energy, Office of Civilian Radioactive Waste Management. OCRWM Transportation Report. DOE/RW-0473. June 1995. P. 15.

direct route from the nearest interstate highway or state alternative route. Other route deviations are allowed for rest stops, fuel, and vehicle repairs, or because of emergency conditions.

In designating alternative routes to interstate highways for spent fuel shipments, states are required to use DOT guidelines or equivalent analytical procedures that would "minimize radiological risk" from the routes selected. States also must conduct "substantive consultation" with all local jurisdictions and other states that would be affected by an alternative route designation. Such a route may be designated by a state as a mandatory or optional alternative to a particular segment of interstate highway. The authority to designate alternative routes has been used by several states.[47]

Although the Hazardous Materials Transportation Act authorizes DOT to regulate spent fuel shipment routes by any mode of transportation, no rail or barge routing regulations analogous to HM-164 have been issued. The lack of such regulations may result from the limited authority of state and local governments to regulate rail and barge traffic, so that federal preemption, as imposed for highway routing, has not been considered necessary. However, DOE is expected to develop its own highway, rail, and barge route selection criteria for spent fuel shipments to a federal repository or central storage facility.[48]

Potential Routes to Yucca Mountain

Because commercial spent fuel is currently stored at reactor sites in nearly every region of the United States, most states have potential transportation routes to Yucca Mountain. Virtually all shipments to the site are expected to take place by highway or rail, with possible exceptions being short barge shipments to railheads from rail-inaccessible nuclear plants located on navigable waterways.

No preferred rail or highway routes have yet been selected by DOE for spent fuel shipments to Yucca Mountain. Nevertheless, because most nuclear power plants are in the eastern half of the country, and Yucca Mountain is in the West, major east-west rail and highway links can be identified as likely candidates. Rail lines and highways connecting reactor sites to the major trunklines can also be readily identified, usually with multiple alternatives available. Whether and how heavily any particular route would actually be used would depend on DOE's routing criteria and the choice of transportation mode from each location.

A recent transportation study for DOE evaluated rail access to the Yucca Mountain site and potential rail routes from all nuclear waste storage locations. For nuclear waste rail shipments to Caliente, Nevada, one of the potential access points to Yucca Mountain, the study found that 265,000 miles of total distance would be traveled from each storage site and that 51,738,000 persons were living within 1 mile

---

[47] Battelle, et al. Identification of Factors for Selecting Modes and Routes for Shipping High-Level Radioactive Waste and Spent Nuclear Fuel. Draft Report for U.S. Department of Transportation. December 1993. P. 14.

[48] OCRWM Transportation Report, op. Cit. P. 18.

of the tracks that could be used. Similar numbers were calculated for the other options examined.[49] Figure 1 shows the representative rail routes to Caliente identified by the study.

Potential highway routes are even more variable, with many of the major east-west interstate highways paralleling major rail routes. Although DOE has generally indicated a preference for rail transport of spent fuel, a recent study for the State of Nevada found that infrastructure and other limitations at nearly half of U.S. nuclear plant sites could lead those sites to choose truck shipments.[50] Figure 2 shows the quickest highway routes from plant sites to Yucca Mountain identified by the State of Nevada, using a DOE computer program.

Radiation Exposure From Routine Shipments

Small amounts of radiation are emitted by spent fuel transportation casks during routine transportation operations. NRC regulations limit radiation exposure levels from spent fuel shipments to 200 millirems per hour at the cask surface, and 10 millirems per hour at two meters from the transport vehicle (10 CFR 71.47). Exposure levels drop rapidly at additional distances; a waste cask that emits 10 millirems per hour at two meters has an exposure level of 1.6 millirems per hour at 10 meters and 0.01 millirem per hour at 100 meters.[51]

For comparison, annual radiation doses to individual members of the public from all non-medical activities licensed by NRC are limited to 100 millirems, and the unrestricted areas near licensed activities cannot have dose rates higher than 2 millirems per hour (10 CFR 20.1301).

Members of the public most likely to be affected by normal shipments of spent nuclear fuel are drivers and passengers of other vehicles (in the case of highway shipments), residents and workers near transportation routes, and persons near stopping points, such as fuel stations. Normally, the radiation dose to any individual member of the public would be extremely low, because each person's proximity to the moving transportation cask would typically last less than a second, or perhaps a few minutes for vehicles traveling the same direction. The dose from a passing cask has been estimated at 0.0005 millirem for a resident 10 meters from a transportation route and 0.00004 millirem at 100 meters.[52] Individuals could receive greater

---

[49] TRW Environmental Safety Systems Inc. Nevada Potential Repository Preliminary Transportation Strategy Study 2, Vol. 1. Prepared for U.S. Department of Energy, Office of Civilian Radioactive Waste Management. February 1996. P. 9-2.

[50] Planning Information Corporation. The Transportation of Spent Fuel and High-Level Waste: A Systematic Basis for Planning and Management at National, Regional, and Community Levels. Prepared for Nevada Nuclear Waste Project Office. September 10, 1996. P. 37.

[51] Electronic mail message from William J. O'Connell, Nuclear Waste Transportation Project Leader, Lawrence Livermore National Laboratory. March 21, 1997.

[52] O'Connel, op. Cit.

exposure, however, if they were near a nuclear waste truck that was stopped for refueling or stuck in a traffic jam.

Minimization of total public exposure (the cumulative exposure of all individuals) is a related consideration during routine transportation operations. According to the National Research Council, an average of 800 cancer deaths are expected per 1 million person-rem of exposure.[53] For example, if 1 million persons each received one-thousandth of a millirem from brief exposures (0.4 seconds at 10 millirems per hour) to passing nuclear waste vehicles, then their total exposure would be 1 rem, and an additional 0.0008 lifetime fatal cancers would be expected. For residents between 10 meters and 1 mile of a transportation route, the average dose per cask shipment is 0.00001 millirem;[54] the total dose would equal the population along transportation routes multiplied by the number of casks shipped on each route. As with individual exposure, total public exposure to normal nuclear waste shipments that meet regulatory standards is expected to be low.

Routing criteria for transportation shipments are expected to emphasize the minimization of total travel time and the number of stops. Other important risk elements for route selection are the total number of persons likely to be traveling in other vehicles on the transportation route, the total population near the transportation route, and the likely number of persons to be encountered near vehicle stops.[55] Analysis of those factors would also be important for minimizing potential radiation exposure from transportation accidents.

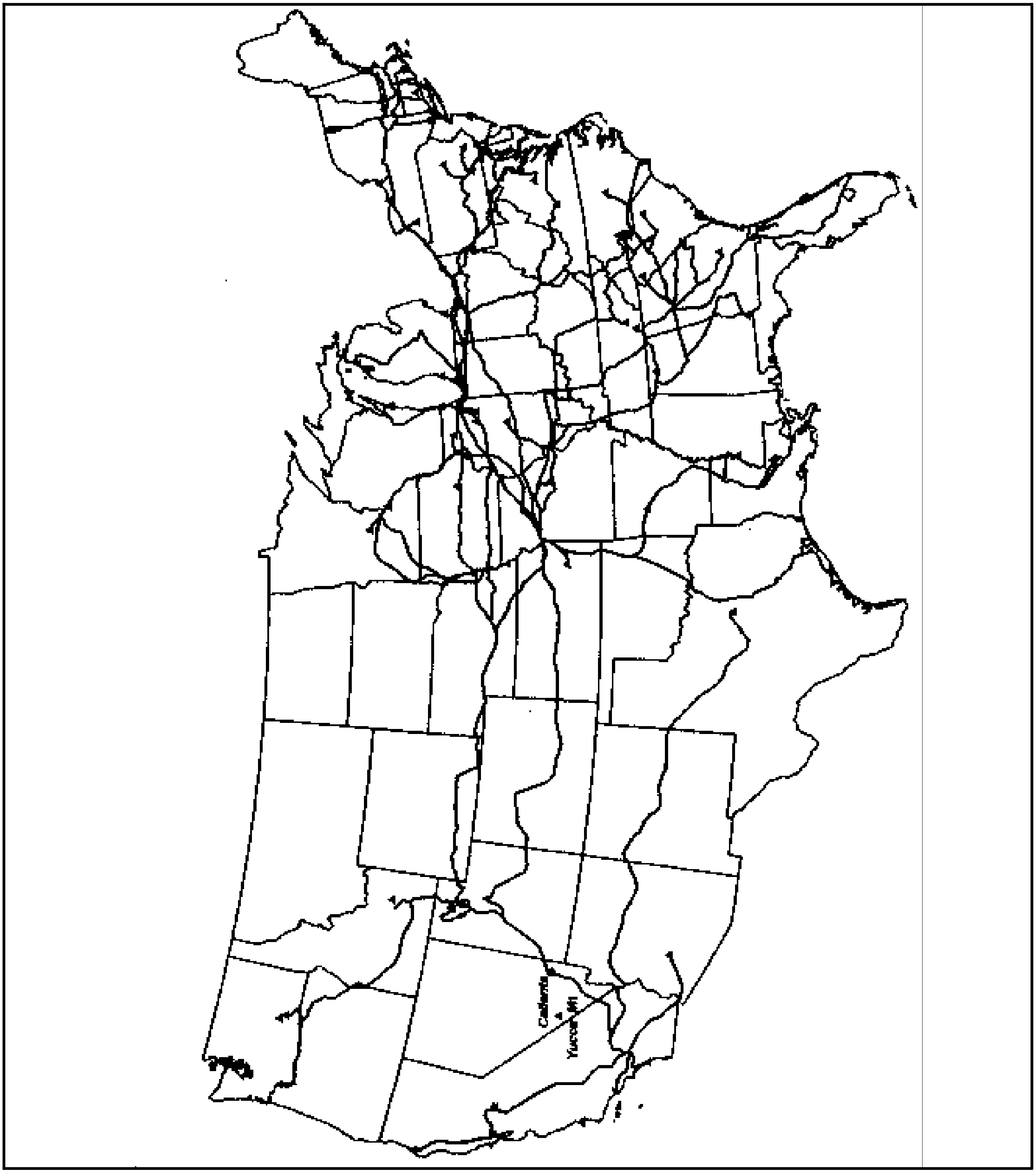
---

[53] Committee on Biological Effects of Ionizing Radiation, National Research Council. Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V. National Academy Press. Washington, D.C., 1990. P. 172.

[54] O'Connell, op. Cit.

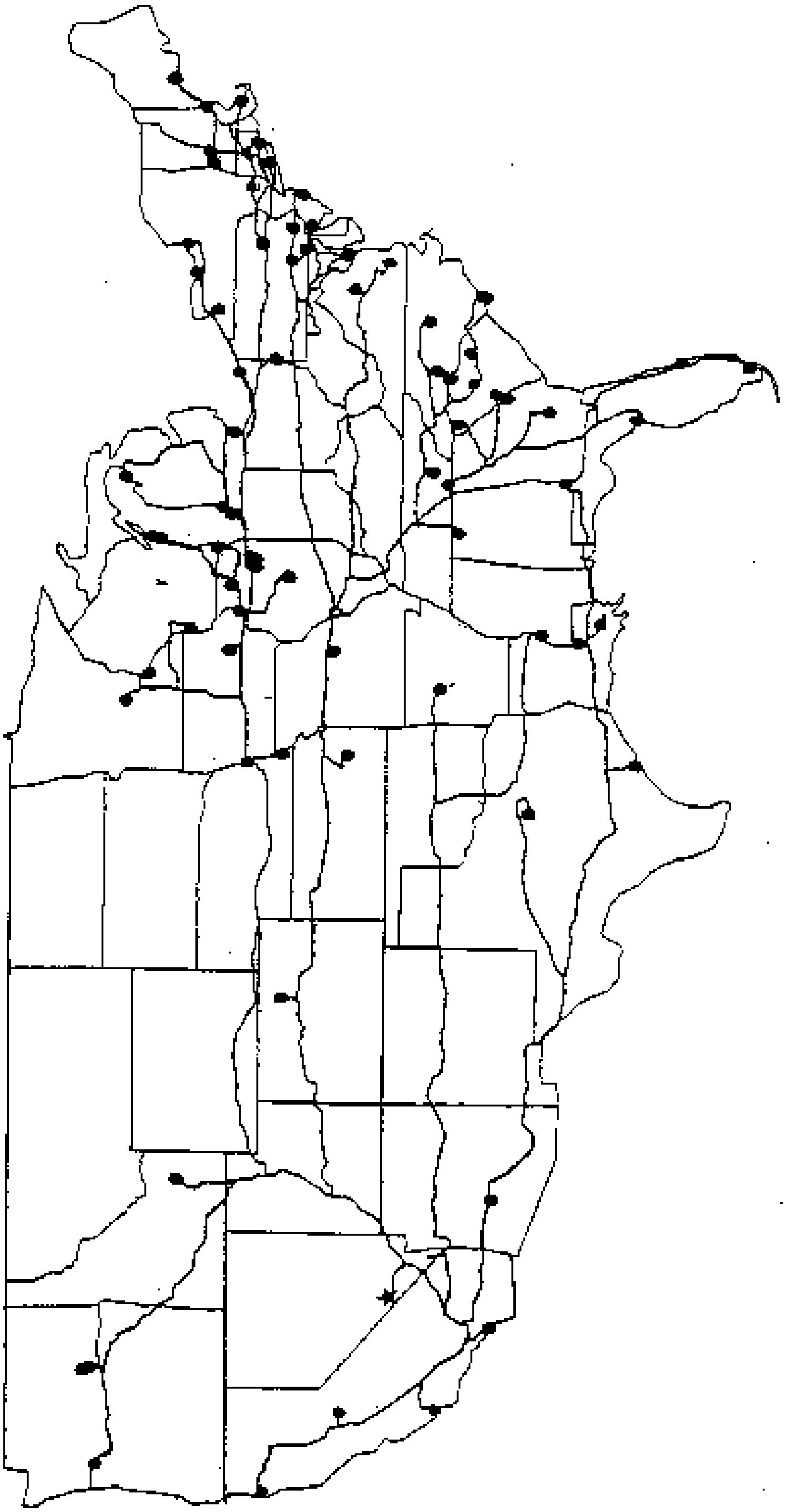
[55] Battelle, Factors for Selecting Modes and Routes. Op. Cit. P. 41.

Figure 1. Representative Rail Routes to Caliente, NV



Source: Nevada Potential Repository Preliminary Transportation Strategy Study 2, DOE.

Figure 2. Potential Highway Routes to Yucca Mountain



Source: Nevada Agency for Nuclear Projects.