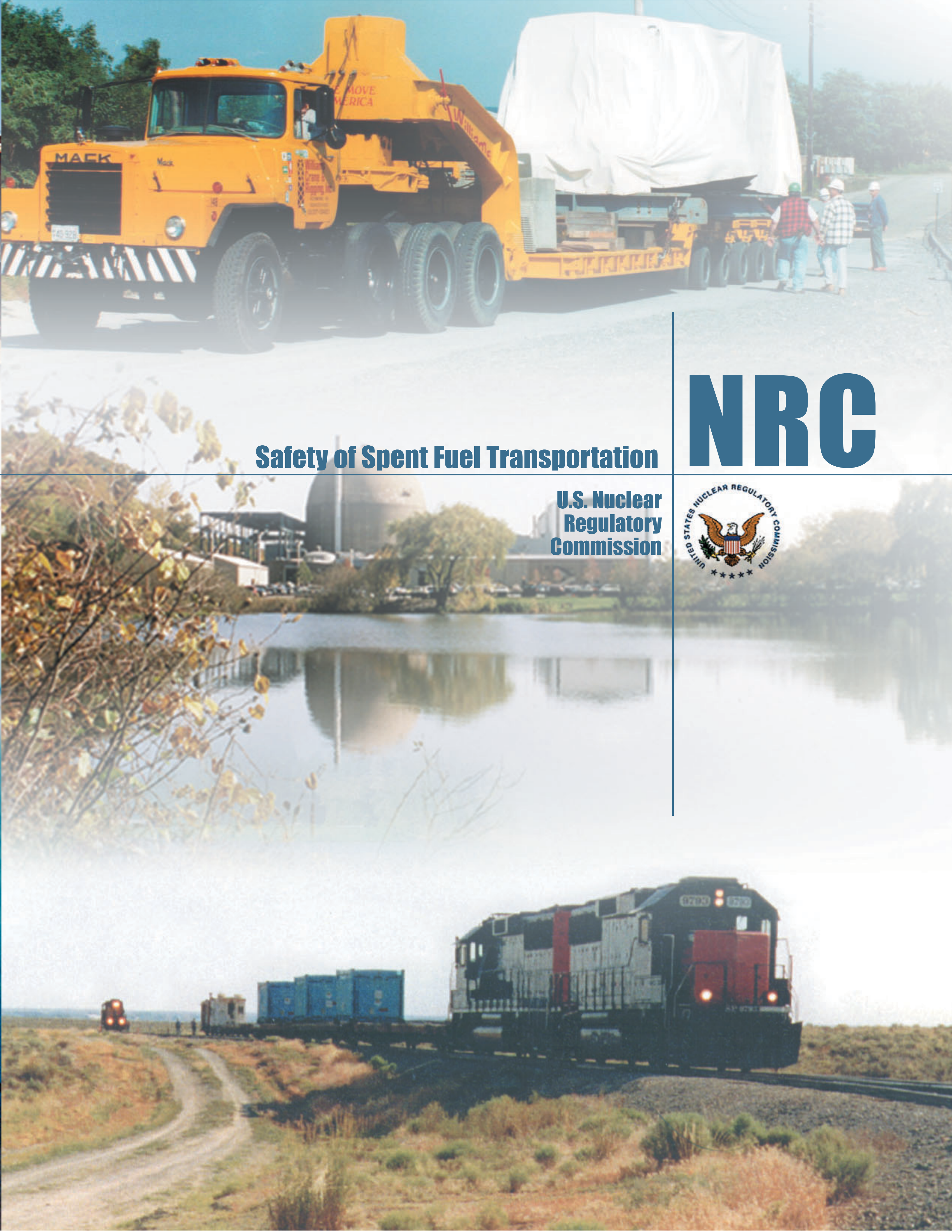


Safety of Spent Fuel Transportation

NRC

U.S. Nuclear
Regulatory
Commission

The Agencies: Who does what?

The U.S. Nuclear Regulatory Commission (NRC) is an independent agency established by the U.S. Congress in 1974 to ensure adequate protection of public health, safety, and the environment in the use of nuclear materials. The NRC regulates commercial nuclear power reactors; non-power research, test, and training reactors; and fuel cycle facilities. The NRC also regulates medical, academic, and industrial uses of nuclear materials, as well as packaging for the transport, storage, and disposal of nuclear materials and waste. In addition, the NRC regulates the design, manufacture, use, and maintenance of containers for high-level radioactive shipments.

The U.S. Department of Transportation (DOT), in coordination with the NRC, sets rules governing the packaging of nuclear materials. With NRC and the affected states, DOT regulates the transport of nuclear materials. The DOT also regulates carriers of nuclear materials, sets standards for transportation routes, and is responsible for international agreements on the transport of all hazardous materials.

The U.S. Department of Energy (DOE), among other things, oversees the development of disposal systems for spent nuclear fuel from the nation's nuclear power plants. This activity is entirely funded by fees collected from nuclear power plant companies and ultimately from rate payers.

The International Atomic Energy Agency (IAEA) serves as the world's principal intergovernmental forum for scientific and technical cooperation in the nuclear field. An agency of the United Nations, the IAEA published regulations for transporting nuclear materials. These regulations serve as a model for the United States and other nations.

Cover photo of tarped cask on trailer courtesy of GE Nuclear Energy. Train photo courtesy of NAC International. Back cover photo of IF-300 cask courtesy of GE Nuclear Energy.

The Nuclear Regulatory Commission

The U.S. Nuclear Regulatory Commission (NRC) regulates the nuclear materials cycle from beginning to end. This cycle begins with the mining of uranium. It continues through the manufacture of fuel, its use in reactors, any temporary storage, and (ultimately) with permanent geologic disposal.

The NRC is dedicated to maintaining public health and safety, protecting the environment, and ensuring our national security in ways that increase public confidence in the agency. The NRC plans to achieve these goals by making its activities more effective, efficient, and realistic, and by reducing unnecessary regulatory burden on all those involved in the use, handling, transport, and disposal of nuclear materials.

The NRC believes that proper handling of nuclear materials will help to ensure the safety of the public and plant workers. Toward that end, the NRC works with other agencies, such as the U.S. Department of Transportation (DOT), the U.S. Department of Energy (DOE), and the International Atomic Energy Agency (IAEA).

This booklet relates to the NRC's role in the safe transportation of spent nuclear fuel from commercial nuclear power plants. Specifically, the NRC oversees the design, manufacture, use, and maintenance of containers for these radioactive shipments.

The NRC has three principal functions:

1. to set standards and develop regulations;

2. to issue licenses for nuclear facilities and nuclear materials users; and

3. to inspect facilities to ensure that NRC regulations are being met.

This is an empty storage/transport container on a semi tractor-trailer rig.

What is Spent Fuel?

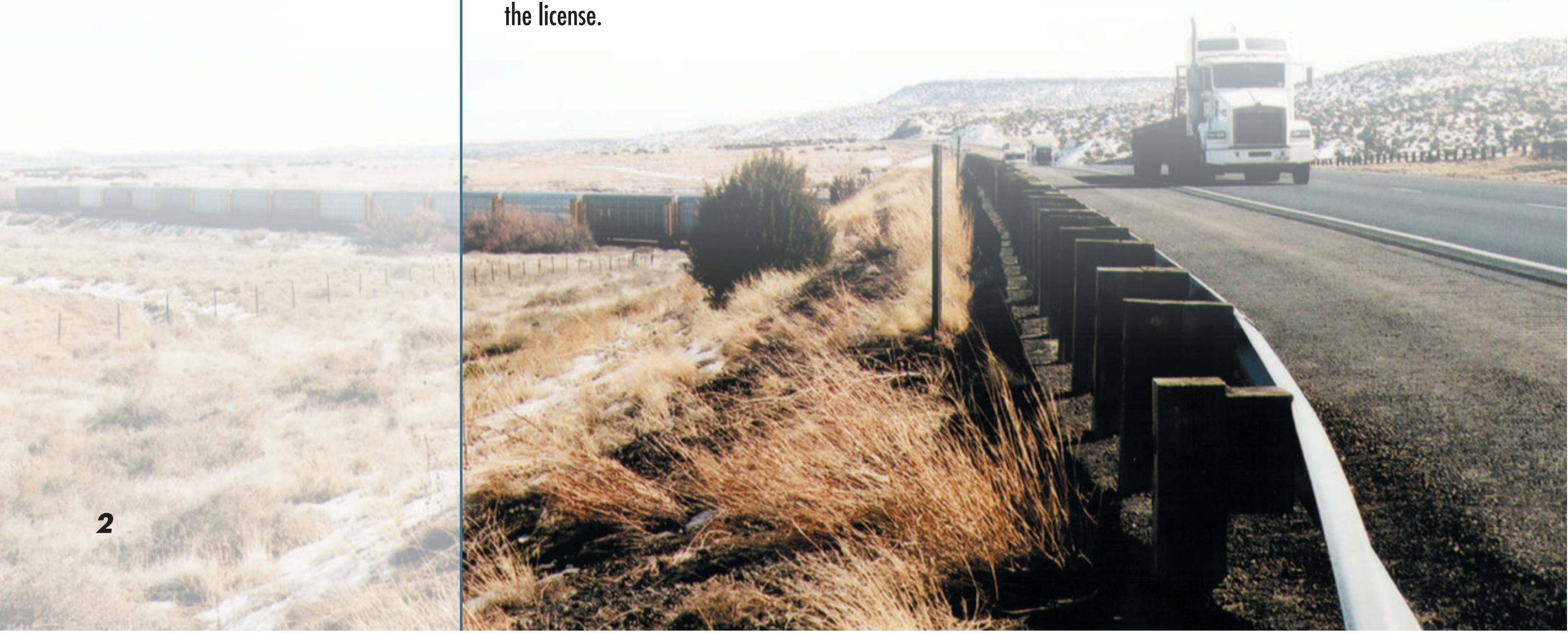
Nuclear reactors produce electricity and, as a waste product, spent fuel. Uranium fuel powers reactors for a number of years, until its potential to produce electrical power is exhausted. The used uranium fuel is then referred to as "spent fuel." Nuclear power plants store spent fuel in enclosed cooling pools and, in some cases, in dry storage casks to await shipment to a temporary storage or permanent disposal facility. The Nuclear Waste Policy Act (NWPA), enacted by Congress in 1992, calls for spent fuel to be moved to a temporary storage facility or to a permanent DOE repository.

The NWPA sets a national policy for safe, permanent disposal of spent nuclear fuel and other radioactive wastes in an underground repository. The action by Congress and the President in July 2002 approving Yucca Mountain will permit the DOE to apply to NRC to construct the repository. The NRC's role under the NWPA is to use its independent judgment as an expert technical agency to decide whether to grant DOE a license to construct a high-level waste repository at Yucca Mountain. Only after extensive review of a DOE application will the NRC be able to judge whether DOE has satisfied the demands of the regulations. The NWPA gives NRC up to four years to decide whether to grant the license.

Radiation

Scientists estimate that nearly 90 percent of all radiation exposure comes from natural sources: radon gas, the human body, outer space, rocks, and soil. Background radiation is naturally present, but its levels can vary greatly. People living in areas with a significant amount of granite, for example, receive more earth-based radiation. Those living or working at high altitudes receive more cosmic radiation. Most natural exposure is from radon, a gas that seeps from the earth's crust into the air we breathe.

The remaining 10 percent of all radiation exposure comes from man-made sources, primarily medical x-rays. Natural and artificial radiation are similar in kind and effect.



Because a repository won't be available for some time, some nuclear power plants are implementing plans for temporary storage on site. Other plants plan to store spent fuel away from the reactor at a temporary site until a permanent repository is built.

Given the widespread locations of power reactors, if a disposal site is finally approved, licensees will need to transport spent fuel to that site safely. These shipments would likely be made on railroads and on public highways.

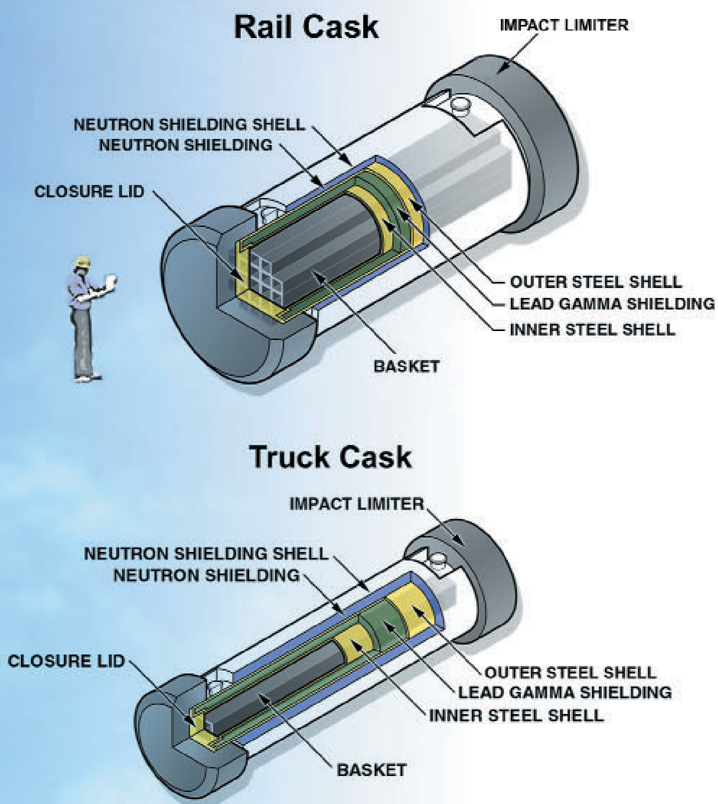
Spent fuel is highly radioactive and must be transported in large, heavy containers that shield the public from exposure. This raises the following frequently asked questions in connection with such shipments:

- How does the NRC protect the public from radioactive waste that is being transported?
- What is the likelihood of these shipments being involved in an accident?
- How well can the transportation containers withstand an accident and prevent the release of nuclear materials?

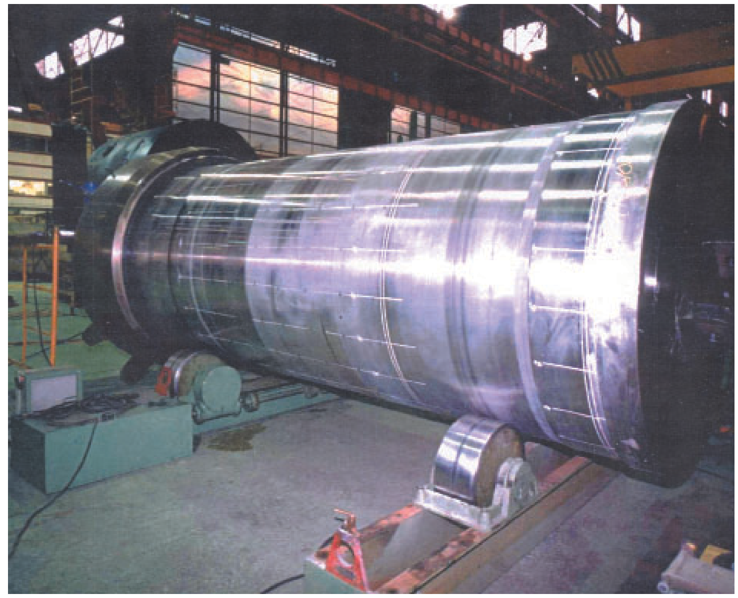
The NRC addresses these and other questions as a part of its ongoing efforts to ensure safe transport. As new technologies and information become available, the NRC continually evaluates its existing safety requirements.

Interim spent fuel storage installation at a reactor site.

The Key to Ensuring Safety: the Spent Fuel Shipping Container



Spent fuel containers are specially designed to protect the public by withstanding accident conditions without releasing their radioactive contents.



The manufacture of spent fuel casks is carefully regulated by the NRC.

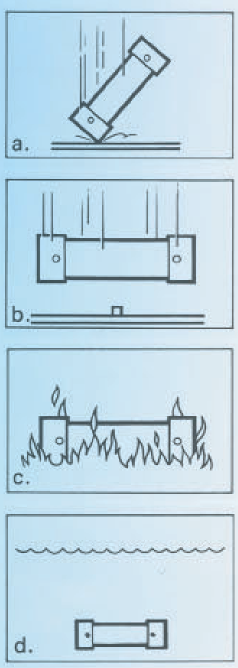
Spent fuel is highly radioactive and must be heavily shielded and tightly contained to be transported safely. An essential component for any safe shipment is a robust spent fuel container, or "cask."

The NRC establishes regulations and standards for the design and construction of robust casks as the primary way to protect the public during transport. Containers used to move spent fuel by rail or highway are designed to withstand severe accidents. U.S. and international regulations require that these containers must pass a series of tests that mimic accident damage. The NRC conducts rigorous reviews to certify that spent fuel containers meet the design standards and test conditions in the regulations.

These containers must be shown, by test or analysis, to survive a sequence of four simulated accident conditions involving impact, puncture, fire, and submersion. During and after the tests, the containers must contain nuclear material, limit doses to acceptable levels, and prevent nuclear reaction.

To protect workers and the public, containers have walls five to 15 inches thick, made of steel and shielding materials, and a massive lid. Truck containers weigh about 25 tons when loaded with 1 to 2 tons of spent fuel. Rail containers can weigh as much as 150 tons and can carry up to 20 tons of spent fuel. The ends of these transportation containers are encased in structures called impact limiters. In the event of an accident, these limiters would crush, absorbing impact forces and protecting the container and its cargo.

Spent fuel containers are tightly sealed and provide shielding for most radiation. However, it is not possible to eliminate all radiation with shielding. Containers provide enough shielding to reduce external radiation to low



The impact (free drop and puncture), fire, and water-immersion tests are considered in sequence to determine their cumulative effects on a given package.

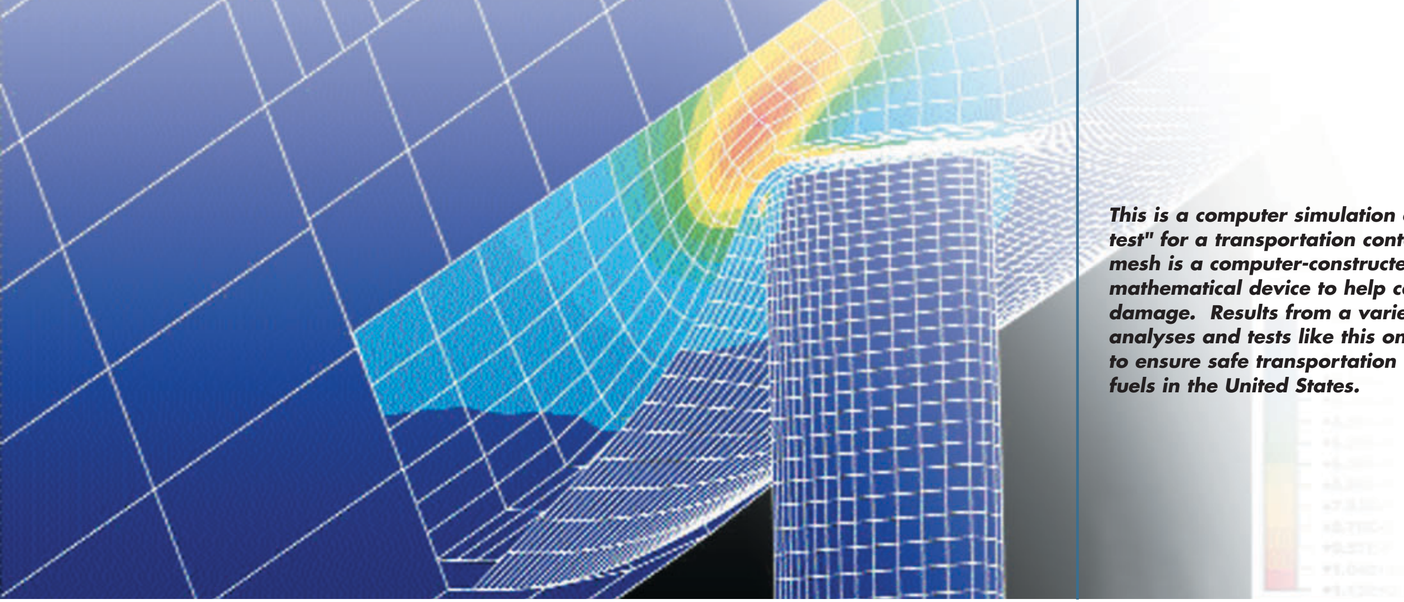
levels that meet DOT and NRC radiation standards for the radiation dose to individuals who might be near the cask during transport.

Container designers may use computer analyses, comparisons with other designs, component testing, scale-model testing, or a combination of these techniques to demonstrate that containers are safe. Most often, they use a combination of computer analyses and physical testing. NRC evaluates each application for a container design, examines the information in depth, and then performs its own calculations. NRC reviewers include structural and materials engineers and safety specialists with advanced degrees and many years of experience.

Once the NRC issues a Certificate of Compliance for a spent fuel container design, fabricators make the containers. Manufacturers and shippers must adhere to a program that ensures the containers continuously meet design specifications.

A scale-model container "drop test" helps researchers understand the forces involved in typical and unusual crash situations.

NRC and DOT regulations also require a number of safety determinations before each spent fuel shipment. These include checks for leaks and tests to ensure that radiation levels and contamination levels are within safe limits. These actions are designed to ensure that all aspects of every spent fuel shipment meet the applicable NRC safety standards.



This is a computer simulation of a "punch test" for a transportation container. The mesh is a computer-constructed mathematical device to help calculate cask damage. Results from a variety of analyses and tests like this one help NRC to ensure safe transportation of spent fuels in the United States.

More than 1,300 spent fuel shipments regulated by the NRC have been completed safely in the U.S. during the past 25 years. Although there have been four accidents involving those shipments, none have resulted in a release of radioactive material.

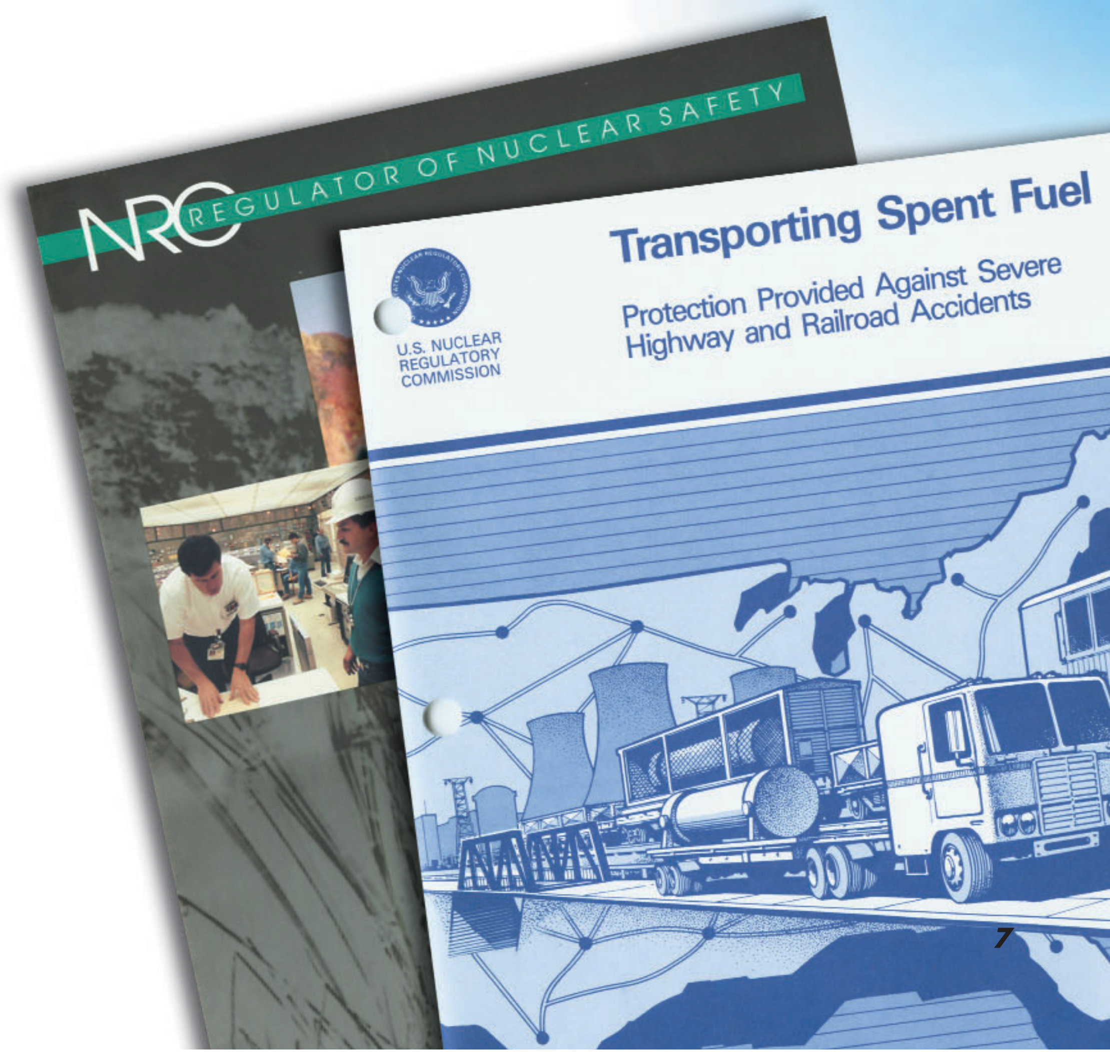
Experience with past shipments confirms that the fundamental safety system is sound. The question becomes, "What might happen if there are *thousands* of future shipments?" The NRC continuously evaluates risks associated with spent fuel transport in a methodical and scientific way. To provide additional confidence, the NRC has sponsored several risk studies related to spent fuel transportation on highways and railroads.

In 1977, the NRC completed a study that has since become the "baseline" for comparison with new information and studies completed since then.

In 1987, the NRC used improved research methods to evaluate how shipping containers react in accidents and to estimate the risk of releasing radioactive materials. The study results added assurances about the ability of shipping casks to withstand an accident and confirmed results of the 1977 study.

Another study, released in March 2000, used improved technology to analyze the ability of containers to withstand an accident. This study concluded that the risk from the increased number of spent fuel shipments that could occur in the first half of this century would be even smaller than originally estimated in 1977.

On the basis of these studies, operational experience, and its own technical reviews, the NRC concluded that the shipment of spent fuel is safe at projected shipment levels. The NRC is continuing to follow developments in spent fuel shipping, including the performance of additional analyses and testing of spent fuel casks, to ensure that the risks remain low.



Understanding the Risks

Researchers use a four-step process to study actual and potential accidents and their effects on a container.

Step 1. Experts use historic records to determine what might happen.

- ***They also gather data on how many spent fuel shipments are likely each year.***
- ***They look at the rate of accidents for rail and highway shipments.***
- ***Researchers look at a large number of accidents that are conceivable.***
- ***They also look at crash impact forces, fires, or punctures that are more severe than those covered by NRC standards.***

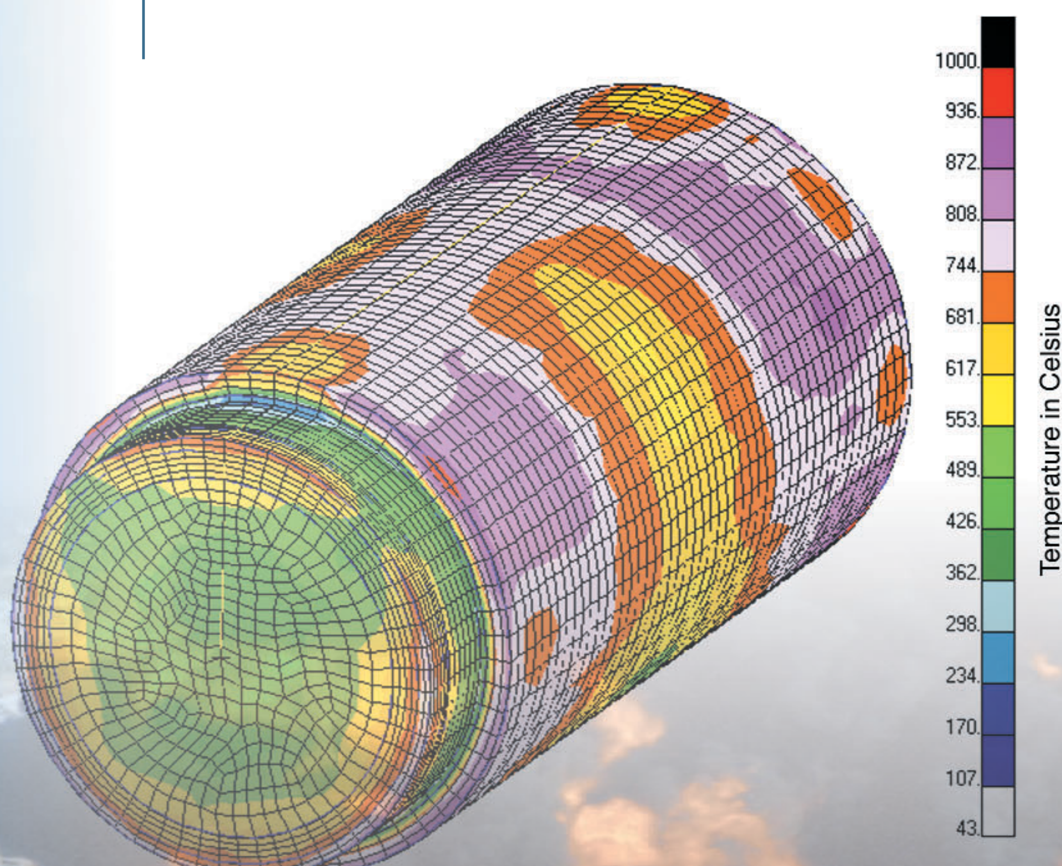
Risk is generally understood to be the possibility of injury, damage, or some kind of loss.

Given that understanding, the spent fuel shipment record in the U.S. has been outstanding to date. Many more shipments have been successfully completed internationally under the same basic safety standards.

While shipping spent fuel does involve risk, NRC studies indicate that this risk is low. As a part of its safety effort, minimizing risk is an important concept to the NRC. The NRC's risk assessment asks the following three questions and then converts the answers into numbers to arrive at a risk value:

- What can go wrong?
- How likely is it?
- If something goes wrong, what are the consequences?

Although the overwhelming majority of spent fuel shipments are accident-free, researchers calculate radiation risks to the public using two scenarios. One scenario involves a journey during which an accident occurs; the other covers the vast majority of journeys that do not involve an accident.



Shown is a computer simulation of the response of a cask to a severe fire environment. Analyses like this and tests are used by NRC to assure safe transportation of spent fuel.

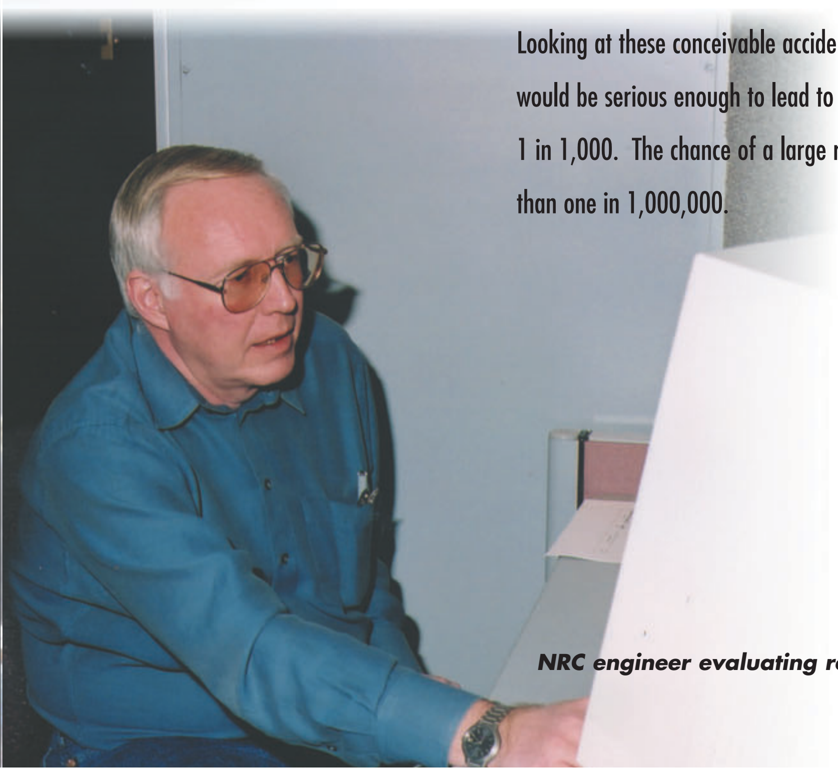
The Accident Scenario

NRC studies show that fewer than 1 in 100 accidents involving a spent fuel container will be more severe than the conditions of the design standards. However, if a very unlikely chain of events occurs, the accident might be severe enough to cause a radioactive release.

To estimate the likelihood and consequences of unusually severe accidents, researchers use a multi-step approach to calculate risk. That approach uses accident data and their experience with past trucking and rail accidents involving other hazardous materials. This also involves determining what kinds of accidents could happen and looking at their potential effects.

According to the DOE Final Environmental Impact Statement (FEIS) for the Yucca Mountain Project, about 11,000 rail or 53,000 truck shipments might be expected during the 24 years of operation of the repository, should it be approved. The chances that any accident would occur during a spent fuel shipment are about 1 in 10,000 for rail shipments and 1 in 1,000 for highway transport. Put another way, these estimates indicate that 1 to 50 accidents involving casks are conceivable in the process of moving all current spent fuel to a permanent repository.

Looking at these conceivable accidents, the chance that even one would be serious enough to lead to even a small release is about 1 in 1,000. The chance of a large release is estimated to be less than one in 1,000,000.



NRC engineer evaluating results of a container test.

Step 2. Engineers use complex computer programs to estimate how the parts of a shipping container might be damaged by collisions or fires.

- ***They gather data on how much spent fuel each container will carry.***
- ***They analyze how the fuel might respond in a given type of accident.***
- ***They calculate the temperature of the container and the spent fuel itself during a long-term fire.***

This information provides estimates on the size of any potential leak and how much nuclear material might escape.

Step 3. Researchers match accident scenarios from Step 1 with the assessments from Step 2 to determine the chance of severe damage to the container or its contents.

Step 4. Researchers compute a risk estimate with a special computer program. The program takes accident probability estimates, expected numbers of shipments, route data (like population densities), weather data (to estimate how any release might be spread by wind), and radiological dose data to produce a risk estimate.

The Accident-Free Scenario

In an accident-free journey, nothing goes wrong and no nuclear material is released from the container. In this scenario, the total of all radiological exposures, or doses, that could be received by all people along the transportation route is calculated. Because spent fuel, even fully contained, still emits low levels of radiation through the container walls, researchers use route and population information to estimate the number of people who could be exposed and the total radiation dose that they might receive.

The risk to the public from an accident-free journey results from the low-level radiation field that surrounds the spent fuel container. If the container is moving past a person, perhaps someone standing along the highway or railroad track, the exposure is brief and well below regulatory limits. Exposure will vary depending upon the speed of the train or tractor-trailer rig and the distance the person is standing from the highway or track. The very low dose to each person along the route is added to obtain the total population dose. As a basis for comparison, a passenger traveling round-trip by air from New York to Los Angeles receives a background radiation dose that is 25 times greater than the dose to persons closest to a typical spent fuel shipment.

The Bottom Line

The NRC believes that shipments of spent fuel in the U.S. are safe. This belief is based on the NRC's confidence in the shipping containers that it certifies and its ongoing research in transportation safety.

- The NRC ensures that shipping containers are robust by:
  - Regulating the design and construction of shipping containers.
  - Reviewing designs and independently checking a container's ability to meet accident conditions.
  - Ensuring that containers are built, maintained, and used properly.

- The NRC also follows an aggressive program to investigate and assess the risks involved in spent fuel shipments:
  - Analyzing spent fuel transportation records to understand safety issues better.
  - Evaluating new transportation issues, such as increased shipment levels, denser populations along some routes, and other factors.
  - Using new technology to estimate current and future levels of potential risk to the public.

Although there will always be a slight chance that an accident will cause a release of nuclear material, the NRC has found that the likelihood of such an event and the associated risk to the public are extremely low. Even so, the NRC will continue to be vigilant about public safety as an essential part of its mission.

Spent Fuel Transport Security

The NRC also regulates the physical protection of spent nuclear fuel in transit against sabotage or other malicious acts. The NRC's current physical protection regulations for spent fuel transportation include:

- Pre-shipment coordination with law enforcement agencies
- Pre-shipment notice of States and NRC
- In-transit shipment call-in to communications center
- Shipment monitoring
- Armed escorts (in populated areas)
- Immobilization devices

Since September 11, 2001, the NRC has taken additional steps to protect the public. These steps involve a heightening of the security posture, including new measures taken to protect nuclear facilities and regulated activities, such as spent fuel transportation, and orders that NRC has issued to licensees.

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