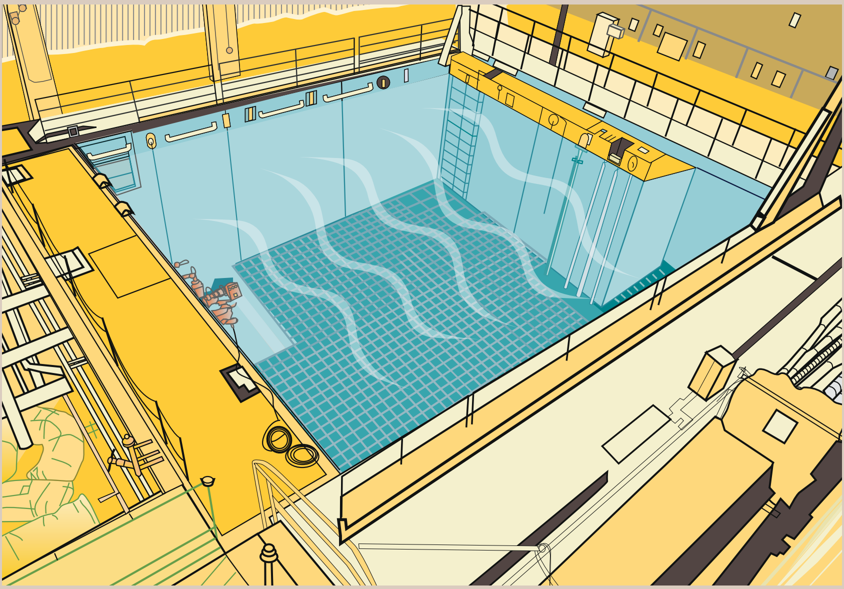
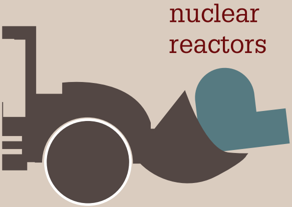
# Radioactive Waste

## Spent Fuel Pool

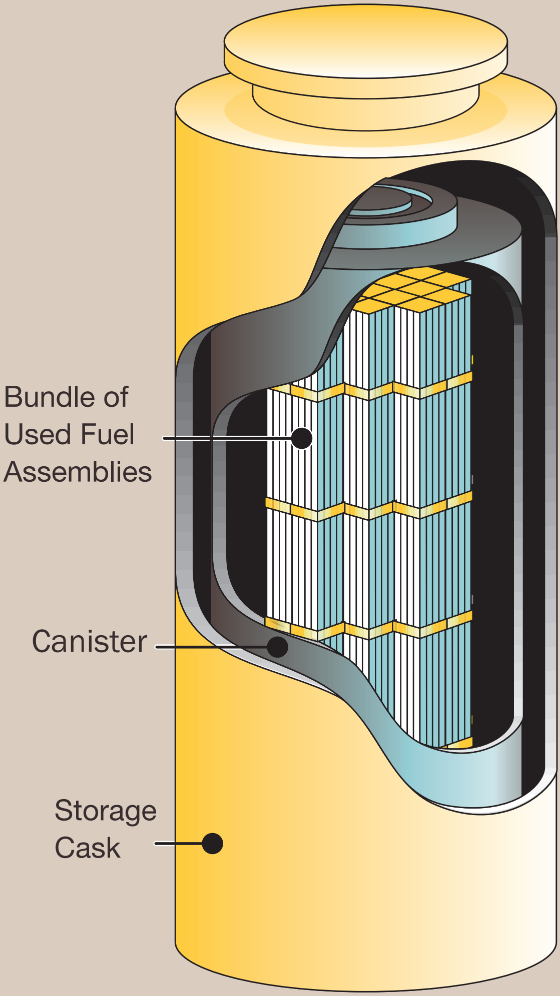


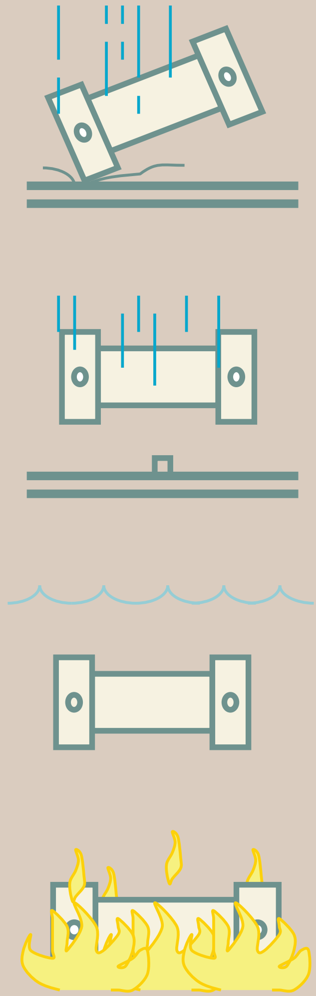
## Facilities Undergoing Decommissioning

| 17 nuclear reactors | 18 complex material sites | 11 research and test reactors | 1 fuel cycle facility | 11 uranium recovery facilities |
|---|---|---|---|---|



# Spent Fuel Storage Cask



**ENSURE SAFE SHIPPING CONTAINERS**

# Low-Level Radioactive Waste Disposal

Low-level radioactive waste (LLW) includes items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. This waste typically consists of contaminated protective shoe covers and clothing, wiping rags, mops, filters, reactor water treatment residues, equipment and tools, medical tubes, swabs, injection needles, syringes, and laboratory animal carcasses and tissue.

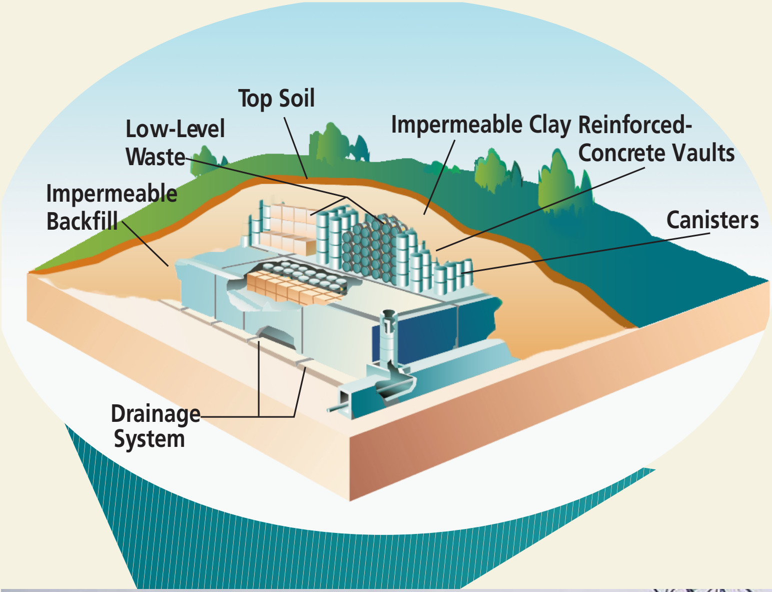
The radioactivity can range from just-above-background levels found in nature to very high levels from the parts inside the reactor vessel in a nuclear power plant. Licensees store some lower level radioactive waste on site until it has decayed and lost its radioactivity. Then it can be disposed of as ordinary trash. Waste that does not decay fairly quickly is stored until amounts are large enough for shipment to an LLW disposal site in containers approved by DOT and the NRC.

Commercial LLW is disposed of in facilities licensed by either the NRC or Agreement States in accordance with health and safety requirements. The facilities are designed, constructed, and operated to meet safety standards. The operator of the facility also extensively characterizes the site on which the facility is located and analyzes how the facility will perform in the future. Current LLW disposal uses shallow land disposal sites with or without concrete vaults (see Figure 40).

The NRC has developed a classification system for LLW based on its potential hazards. It has specified disposal and waste requirements for each of the three classes of waste—Classes A, B, and C—that are acceptable for disposal in near-surface facilities. These classes have progressively higher levels of concentrations of radioactive material, with A having the lowest and C having the highest level. Class A waste accounts for approximately 96 percent of the total volume of LLW. Determination of the classification of waste is a complex process. A fourth class of LLW, greater than Class C, is not generally acceptable for near-surface, shallow-depth disposal. By law, DOE is responsible for disposal of greater than Class C waste under an NRC license.

The volume and radioactivity of waste vary from year to year based on the types and quantities of waste shipped each year. Waste volumes currently include several million cubic feet each year from reactor facilities undergoing decommissioning and from cleanup of contaminated sites.

**Figure 40. Low-Level Waste Disposal**




*This LLW disposal site accepts waste from States participating in a regional disposal agreement.*

The Low-Level Radioactive Waste Policy Amendments Act of 1985 gave the States responsibility for the disposal of LLW. The Act authorized States to do the following:

- Form regional compacts, with each compact to provide for LLW disposal site access.
- Manage LLW import to, and export from, a compact.
- Exclude waste generated outside a compact.

*See Appendix P for Regional Compacts*

The States have licensed four active LLW disposal facilities:

- Barnwell, located in Barnwell, SC—Previously, Barnwell accepted waste from all U.S. generators. As of July 2008, Barnwell accepts waste from the Atlantic Compact States (Connecticut, New Jersey, and South Carolina). The State of South Carolina licenses Barnwell to receive Classes A, B, and C of LLW.
- EnergySolutions, located in Clive, UT—EnergySolutions accepts waste from all regions of the United States. Utah licenses EnergySolutions for Class A waste only.
- Hanford, located in Hanford, WA—Hanford accepts waste from the Northwest Compact States (Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, Wyoming) The Rocky Mountain Compact States (Colorado, Nevada and New Mexico). The State of Washington licenses Hanford to receive Classes A, B, and C of LLW.
- Waste Control Specialist (WCS), located in Andrews, TX—The State of Texas licensed WCS in 2009 to receive Classes A, B, and C of LLW from the Texas Compact, which consists of Texas and Vermont. WCS is receiving LLW as of 2011.

Closed LLW disposal facilities licensed by the NRC or Agreement States include the following:

- Beatty, NV, closed 1993
- Sheffield, IL, closed 1978
- Maxey Flats, KY, closed 1977
- West Valley, NY, closed 1975

# High-Level Radioactive Waste Management

## Spent Nuclear Fuel Storage

Commercial spent nuclear fuel, although highly radioactive, is stored safely and securely in 35 States. This includes 31 States with operating nuclear power reactors, where spent fuel is safely stored on site in spent fuel pools and in some dry casks. The remaining four States—Colorado, Idaho, Maine, and Oregon—do not have operating power reactors but are safely storing spent fuel at storage facilities. Waste can be stored safely in pools or casks for 100 years or more.

As of January 2012, the amount of commercial spent fuel in safe storage at commercial nuclear power plants was an estimated 67,000 metric tons. The amount of spent fuel in storage at commercial nuclear power plants is expected to increase at a rate of approximately 2,000 metric tons per year. The NRC licenses and regulates the storage of spent fuel, both at commercial nuclear power plants and at storage facilities located away from reactors.

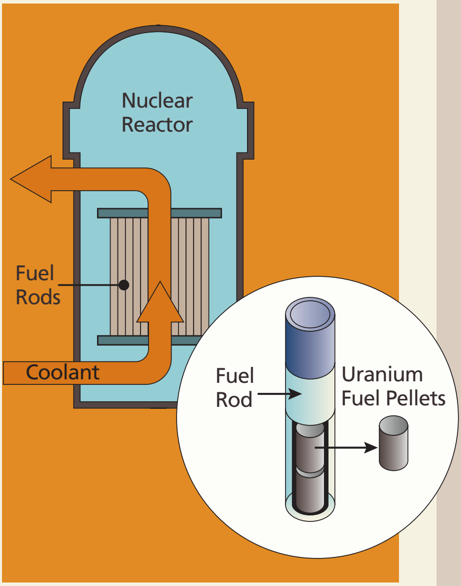
*See Appendix N and O for dry spent fuel storage and licensees information.*

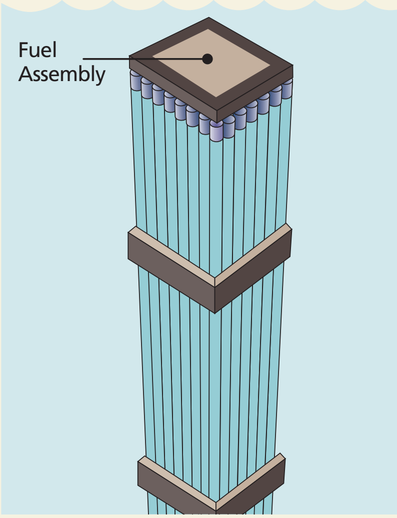
Most reactor facilities were not designed to store the full amount of spent fuel that the reactor would generate during its operational life. Facilities originally planned to store spent fuel temporarily in deep pools of continuously circulating water that cools the spent fuel assemblies and provides shielding from radiation. After a few years, the facilities were expected to send the spent fuel to a recycling plant. However, in 1977, the Federal Government declared a moratorium on recycling spent fuel in the United States. Although the ban was later lifted, recycling has not been pursued.

To cope with the spent fuel they were generating, facilities expanded their storage capacity by using high-density storage racks in their spent fuel pools (see Figure 42). However, spent fuel pools are not a permanent storage solution. To provide supplemental storage, a portion of spent fuel inventories is stored in dry casks on site. These facilities are called independent spent fuel storage installations (ISFSIs) and are licensed by the NRC. These large casks are typically made of leak-tight, welded, and bolted steel and concrete surrounded by another layer of steel or concrete. The spent fuel sits in the center of the nested canisters in an inert gas. Dry cask storage shields people and the environment from radiation and keeps the spent fuel inside dry and nonreactive (see Figure 43).

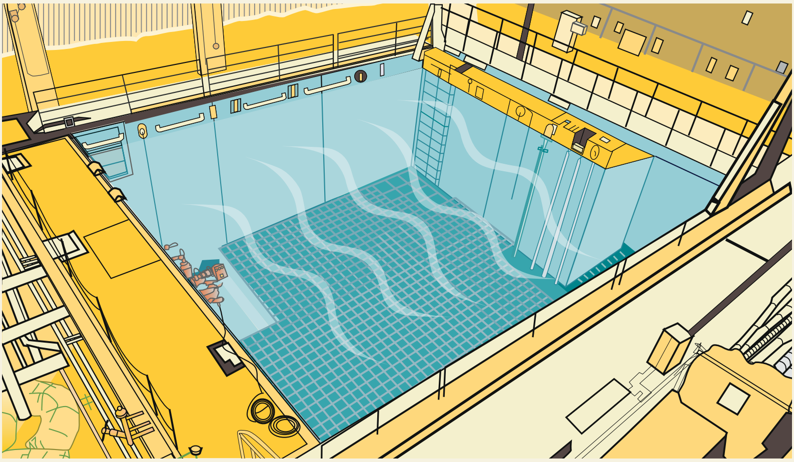
**Figure 41. Spent Fuel Generation and Storage after Use**

*1 A nuclear reactor is powered by enriched uranium-235 fuel. Fission (splitting of atoms) generates heat, which produces steam that turns turbines to produce electricity. A reactor rated at several hundred megawatts may contain 100 or more tons of fuel in the form of bullet-sized pellets loaded into long metal rods that are bundled together into fuel assemblies. PWRs contain between 150 and 200 fuel assemblies. BWRs contain between 370 and 800 fuel assemblies.*

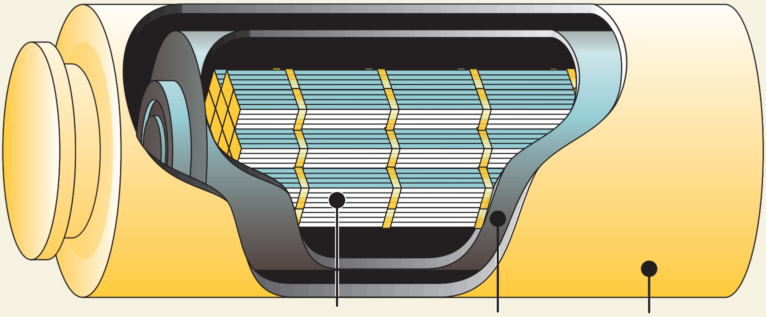



*2 After about 6 years, spent fuel assemblies—typically 14 feet (4.3 meters) long and containing nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs—are removed from the reactor and allowed to cool in storage pools for a few years. At this point, the 900-pound (409-kilogram) assemblies contain only about one-fifth the original amount of uranium-235.*



*3 Commercial light-water nuclear reactors store spent radioactive fuel in a steel-lined, seismically designed concrete pool under about 40 feet (12.2 meters) of water that provides shielding from radiation. Water pumps supply continuously flowing water to cool the spent fuel. Extra water for the pool is provided by other pumps that can be powered from an onsite emergency diesel generator. Support features, such as water-level monitors and radiation detectors, are also in the pool. Spent fuel is stored in the pool until it can be transferred to dry casks on site (as shown in Figure 42) or transported off site to a high-level radioactive waste disposal site.*

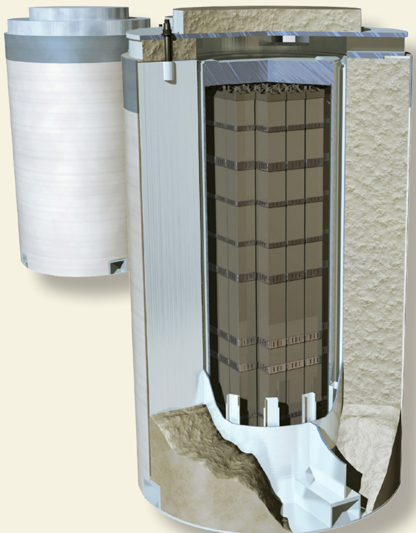


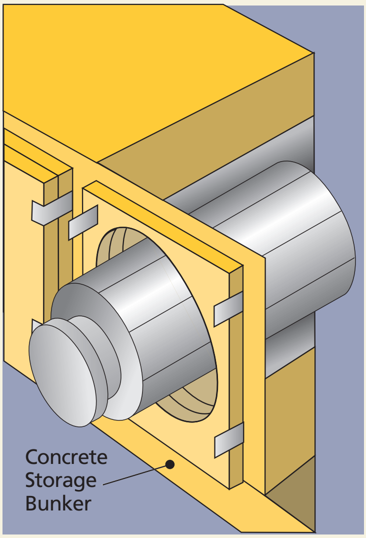

Source: DOE and the Nuclear Energy Institute

## Figure 42. Dry Storage of Spent Nuclear Fuel

*At some nuclear reactors across the country, spent fuel is kept on site, typically above ground, in systems basically similar to the ones shown here.*

*1 Once the spent fuel has sufficiently cooled, it is loaded into special canisters that are designed to hold nuclear fuel assemblies. Water and air are removed. The canister is filled with inert gas, welded shut, and rigorously tested for leaks. It is then placed in a cask for storage or transportation. The NRC has approved the storage of up to 40 PWR assemblies and up to 68 BWR assemblies in each canister. The dry casks are then loaded onto concrete pads.*






*2 The canisters can also be stored in aboveground concrete bunkers, each of which is about the size of a one-car garage.*

Radioactive Waste

Currently, there are 65 licensed ISFSIs in the United States. As of 2012, NRC-licensed ISFSIs were storing spent fuel in over 1,161 loaded dry casks (see Figure 44). The NRC authorizes storage of spent fuel at an ISFSI under two licensing options: (1) site-specific licensing and (2) general licensing. Site-specific licenses granted by the NRC after a safety review contain technical requirements and operating conditions for the ISFSI and specify what the licensee is authorized to store at the site. The initial and renewal license terms for an ISFSI are not to exceed 40 years from the date of issuance. A general license from the NRC authorizes a licensee who operates a nuclear power reactor to store spent fuel on site in dry storage casks. Under the general license, the authority to use a storage cask is tied to the cask's certificate of compliance (CoC) term. A CoC is issued to the cask vendor through rulemaking. Several dry storage cask designs have received certificates. Initial and renewed CoCs are issued for terms not to exceed 40 years.

At least 30 days before the certificate expiration date, the cask vendor may apply for renewal. If the cask vendor does not apply for renewal, a general licensee may apply for renewal. Before using the cask, general licensees must certify that the cask meets the conditions in the certificate, that the concrete pads under the casks can adequately support the loads, and that the levels of radiation from the casks meet NRC standards. Specific license and CoC renewal applications must include an analysis that considers the effects of aging on structures, systems, and components of safety for the requested renewal term.

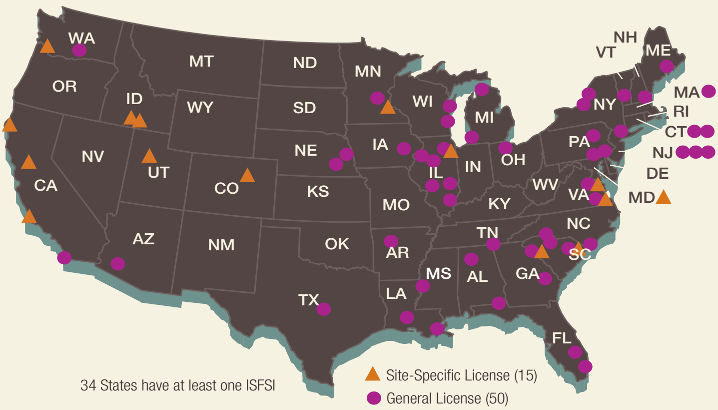
## Public Involvement

The public can participate in decisions about spent fuel storage, as it can in many licensing and rulemaking decisions. The Atomic Energy Act of 1954, as amended, and the NRC's own regulations provide the opportunity for public hearings for site-specific licensing actions and allow for public comments on certificate rulemakings. Interested members of the public may also file petitions for rulemaking. Additional information on ISFSIs is available on the NRC Web site (see the Web Link Index).

## Spent Nuclear Fuel Disposal

The current U.S. policy governing permanent disposal of high-level radioactive waste is defined by the Nuclear Waste Policy Act of 1982, as amended, and the Energy Policy Act of 1992. These acts specify that high-level radioactive waste will be disposed of underground in a deep geologic repository.

## Figure 43. Licensed/Operating Independent Spent Fuel Storage Installations by State




ALABAMA
- ● Browns Ferry
- ● Farley

ARIZONA
- ● Palo Verde

ARKANSAS
- ● Arkansas Nuclear

CALIFORNIA
- ▲ Diablo Canyon
- ▲ Rancho Seco
- ● San Onofre
- ▲ Humboldt Bay

COLORADO
- ▲ Fort St. Vrain

CONNECTICUT
- ● Haddam Neck
- ● Millstone

FLORIDA
- ● St. Lucie
- ● Turkey Point

GEORGIA
- ● Hatch

IDAHO
- ▲ DOE: TMI-2 (Fuel Debris)
- ▲ Idaho Spent Fuel Facility

ILLINOIS
- ● Braidwood
- ● Byron
- ▲ GE Morris (Wet)
- ● Dresden
- ● La Salle
- ● Quad Cities

IOWA
- ● Duane Arnold

LOUISIANA
- ● River Bend
- ● Waterford

MAINE
- ● Maine Yankee

MARYLAND
- ▲ Calvert Cliffs

MASSACHUSETTS
- ● Yankee Rowe

MICHIGAN
- ● Big Rock Point
- ● Palisades

MINNESOTA
- ● Monticello
- ▲ Prairie Island

MISSISSIPPI
- ● Grand Gulf

NEBRASKA
- ● Cooper
- ● Ft. Calhoun

NEW HAMPSHIRE
- ● Seabrook

NEW JERSEY
- ● Hope Creek
- ● Salem
- ● Oyster Creek

NEW YORK
- ● Indian Point
- ● FitzPatrick
- ● Ginna

NORTH CAROLINA
- ● Brunswick
- ● McGuire

OHIO
- ● Davis-Besse

OREGON
- ▲ Trojan

PENNSYLVANIA
- ● Limerick
- ● Susquehanna
- ● Peach Bottom

SOUTH CAROLINA
- ●▲ Oconee
- ●▲ Robinson
- ● Catawba

TENNESSEE
- ● Sequoyah

TEXAS
- ● Comanche Peak

UTAH
- ▲ Private Fuel Storage

VERMONT
- ● Vermont Yankee

VIRGINIA
- ●▲ Surry
- ●▲ North Anna

WASHINGTON
- ● Columbia

WISCONSIN
- ● Point Beach
- ● Kewaunee

DOE submitted its license application to the NRC on June 3, 2008, for Yucca Mountain in Nevada. The NRC formally accepted it for review in September 2008 and began the detailed technical review and associated adjudicatory activities. In 2009, President Barack Obama announced that the administration would terminate the Yucca Mountain program while developing a disposal alternative.

In September 2011, the NRC completed an orderly closure of its Yucca Mountain activities. As part of the orderly closure, the NRC prepared three technical evaluation reports, in addition to one volume of a safety evaluation report published earlier. The NRC also prepared 46 additional reports that capture important technical or regulatory information, insights, and lessons learned from more than 25 years of work during the prelicensing and licensing phases of the Yucca Mountain project.

On January 29, 2010, President Obama directed the Secretary of Energy to establish the Blue Ribbon Commission on America's Nuclear Future (BRC) to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new strategy. The BRC provided its final recommendations to the Secretary of Energy on January 26, 2012. Several of the BRC's recommendations are related to ongoing areas of NRC regulatory activities. The key areas in this effort are the nuclear fuel cycle, spent fuel storage and transportation, and high-level waste disposal.

## Reprocessing

In the United States, spent nuclear fuel is stored safely and securely either at a nuclear power plant or at a storage facility away from a plant. Some countries reprocess their spent nuclear fuel to recover fissile material and use it to generate more energy. Although the NRC has not received an application for a reprocessing facility, the agency has completed an initial analysis of the existing regulatory framework in preparation for such an application. The NRC has developed a draft technical basis document for revising the existing regulatory framework for reprocessing facilities, to ensure that a potential commercial reprocessing facility can be licensed efficiently and effectively and operate safely.

# Transportation

The NRC is also involved in the transportation of spent nuclear fuel. It establishes safety criteria for spent fuel shipping casks and certifies cask designs. Casks are designed to meet the following safety criteria under both normal and accident conditions:

- prevent the loss or dispersion of radioactive contents;
- provide shielding and heat dissipation; and
- prevent nuclear criticality (a self-sustaining nuclear chain reaction).

Spent fuel shipping casks must be designed to survive a sequence of tests, including a 9-meter (30-foot) drop onto an unyielding surface, a puncture test, and a fully engulfing fire at 1,475 degrees Fahrenheit (802 degrees Celsius) for 30 minutes. This very severe test sequence, akin to the cask striking a concrete pillar along a highway at a high speed and being engulfed in a very severe and long-lasting fire, simulates conditions more severe than 99 percent of vehicle accidents (see Figure 45).

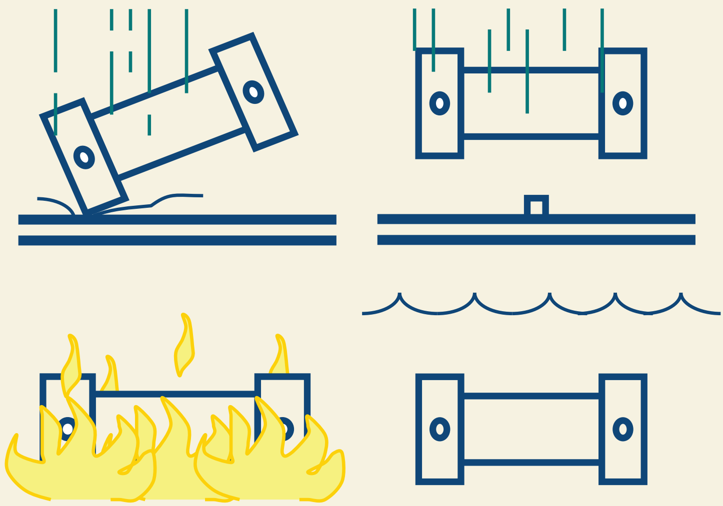
## Principal Licensing and Inspection Activities

The NRC regulates spent fuel transportation through a combination of safety and security requirements, certification of transportation casks, inspections, and a system of monitoring to ensure that requirements are being met. Specifically, each year, the NRC does the following:

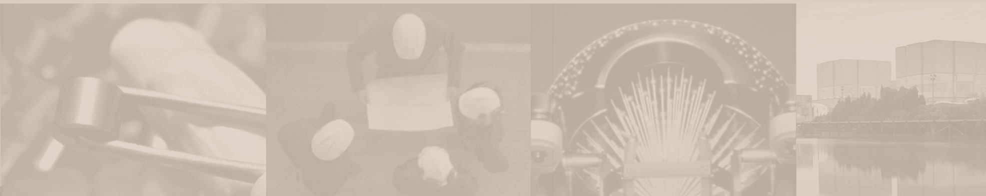
- conducts about 1,000 transportation safety inspections of fuel, reactor, and materials licensees;
- reviews, evaluates, and certifies approximately 80 new, renewal, or amended transport package design applications;
- inspects about 28 dry storage and transport package licensees; and
- reviews and evaluates approximately 150 license applications for the import or export of nuclear materials.

Additional information on materials transportation is available on the NRC Web site (see the Web Link Index).

**Figure 44. Ensuring Safe Spent Fuel Shipping Containers**



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



# Decommissioning

Decommissioning is the safe removal of a nuclear facility from service and the reduction of residual radioactivity to a level that permits release of the property and termination of the license. The NRC rules establish site-release criteria and provide for unrestricted and, under certain conditions, restricted release of a site. The NRC rules also require licensees authorized to possess radioactive materials above a threshold amount to maintain financial assurance that funds will be available when needed for decommissioning.

The NRC regulates the decontamination and decommissioning of materials and fuel cycle facilities, nuclear power plants, research and test reactors, and uranium recovery facilities, with the ultimate goal of license termination. The NRC terminates approximately 150 materials licenses each year. Most of these license terminations are routine, and the sites require little, if any, remediation to meet the NRC's release criteria for unrestricted access. The decommissioning program focuses on the termination of licenses that are not routine, because the sites involve more complex decommissioning activities (see Figure 45).

As of early April 2012, the following facilities were undergoing decommissioning (see Figure 46) under NRC jurisdiction:

- 17 nuclear power and early demonstration reactors
- 18 complex material sites
- 11 research and test reactors
- 1 fuel cycle facility
- 11 uranium recovery facilities

*See Appendices B, J and R for licensees undergoing decommissioning.*

The "Status of the Decommissioning Program 2011 Annual Report" provides additional information on the decommissioning programs of the NRC and Agreement States. More information is on the NRC Web site (see the Web Link Index).

*As part of the decommissioning process, the cooling tower of a nuclear power plant is imploded.*

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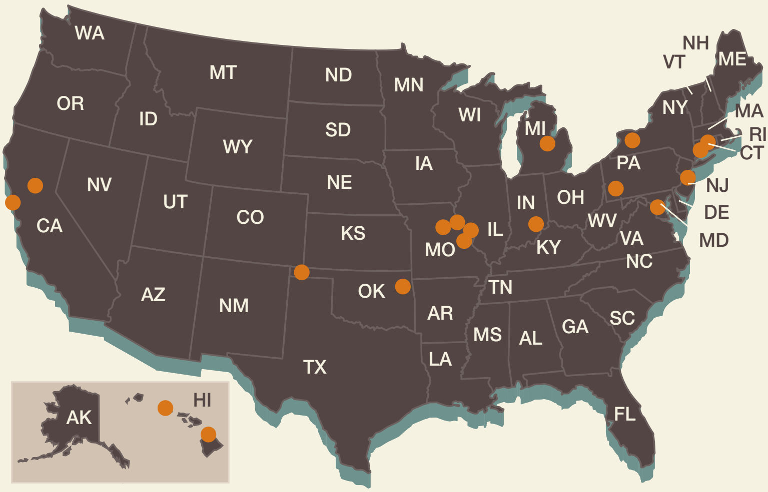
### Figure 45. Locations of NRC-Regulated Complex Material Sites Undergoing Decommissioning




### Figure 46. Facilities Undergoing Decommissioning Under NRC Jurisdiction