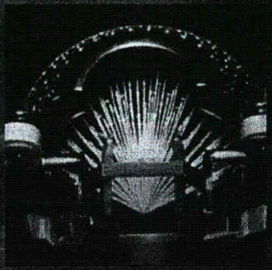
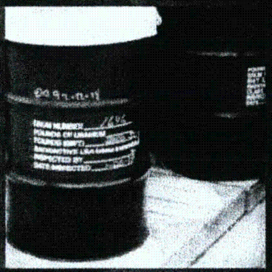
NUCLEAR MATERIALS





Top: Workers using a moisture density gauge. (Photo courtesy: APNGA)

Middle: A Leskel Gamma Knife® headframe uses radiation beams to treat people with brain cancer. (Photo courtesy: Elekta)

Bottom: Yellowcake is produced by uranium recovery facilities and is then transported to a uranium conversion facility.

The NRC regulates nuclear materials for use in medical, industrial, and academic applications. It also regulates the phases of the nuclear fuel cycle, which begins with the uranium recovery, conversion, enrichment, and fabrication facilities that produce nuclear fuel for power plants.

MATERIALS LICENSES

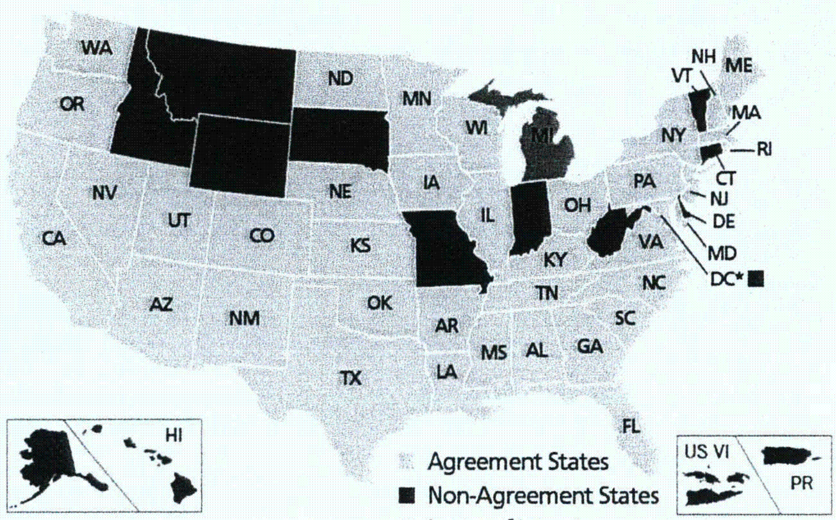
Through agreements with the NRC, many States have assumed regulatory authority over radioactive materials, with the exception of nuclear reactors, fuel facilities, and certain quantities of special nuclear material. These States are called Agreement States, as shown in gold in Figure 30. The NRC and Agreement State regulatory programs are designed to ensure that licensees safely use these materials and do not endanger public health and safety or cause damage to the environment.

The NRC and Agreement States have issued approximately 22,000 licenses for general use of nuclear materials (see Table 8):

- The NRC administers approximately 3,000 licenses.
- 37 Agreement States administer approximately 19,000 licenses.

Reactor- and accelerator-produced radionuclides are used extensively throughout the United States for civilian and military industrial applications; basic and applied research; manufacture of consumer products; academic studies; and medical diagnosis, treatment, and research.

Figure 30. Agreement States



* Includes all major U.S. territories such as Guam.

Table 8. U.S. Materials Licenses by State

State	NRC	Agreement States
	Number of Licenses	
Alabama	17	445
Alaska	63	0
Arizona	11	374
Arkansas	6	218
California	56	1,913
Colorado	19	346
Connecticut	188	0
Delaware	58	0
District of Columbia	41	0
Florida	21	1,707
Georgia	17	503
Hawaii	41	0
Idaho	79	0
Illinois	32	713
Indiana	289	0
Iowa	4	172
Kansas	10	301
Kentucky	8	453
Louisiana	12	527
Maine	2	126
Maryland	80	609
Massachusetts	80	497
Michigan	514	0
Minnesota	12	150
Mississippi	6	334
Missouri	291	0
Montana	89	0
Nebraska	5	148
Nevada	3	248
New Hampshire	6	79
New Jersey	42	672
New Mexico	15	193
New York	27	1,441
North Carolina	17	760
North Dakota	9	77
Ohio	42	657
Oklahoma	19	248
Oregon	4	337
Pennsylvania	59	767
Rhode Island	1	49
South Carolina	15	419
South Dakota	43	0
Tennessee	20	601
Texas	50	1,647
Utah	10	198
Vermont	35	0
Virginia	64	424
Washington	16	421
West Virginia	179	0
Wisconsin	17	328
Wyoming	83	0
Others*	153	0
Total	2,958	19,132

Agreement State (shaded)

* Others include major U.S. territories.

Note: The NRC and Agreement State data are the latest available as of March 2011.
The NRC licenses Federal agencies in Agreement States.

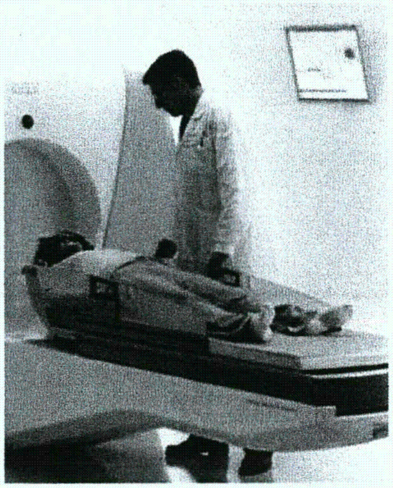
MEDICAL AND ACADEMIC

In both medical and academic settings, the NRC reviews the facilities, personnel, program controls, and equipment to ensure the safety of the public, patients, and workers who might be exposed to radiation.

Medical

The NRC and Agreement States issue licenses to hospitals and physicians for the use of radioactive materials in medical treatments. In addition, the NRC develops guidance and regulations for use by licensees and maintains a committee of medical experts to obtain advice about the use of radioactive materials in medicine. The NRC regulations require that physicians and physicists have special training and experience to practice radiation medicine. The training emphasizes safe operation of nuclear-related equipment and accurate recordkeeping. The Advisory Committee on the

Photo courtesy: Nordion



Gamma Knife® used for treating brain tumors.

Medical Uses of Isotopes comprises physicians, scientists, and other health care professionals who advise the NRC staff on initiatives in the medical uses of radioactive materials.

Nuclear Medicine

About one-third of all patients admitted to hospitals are diagnosed or treated using radioactive materials. This branch of medicine is known as nuclear medicine, and the radioactive materials for treatment are called radiopharmaceuticals. Doctors of nuclear medicine use radiopharmaceuticals to diagnose patients through in vivo tests (direct administration of radiopharmaceuticals to patients) or in vitro tests (the addition of radioactive materials to lab samples taken from patients). Doctors also use radiopharmaceuticals and radiation-producing devices to treat conditions such as hyperthyroidism and certain forms of cancer and to ease pain caused by bone cancer. In the past decade, the use of nuclear medicine for treatment and diagnoses has increased significantly.

Diagnostic Procedures

For most diagnostic procedures in nuclear medicine, a small amount of radioactive material is administered, either by injection, inhalation, or oral administration. The radiopharmaceutical collects in the organ or area being evaluated, where it emits photons. These photons can be detected by a device known as a gamma camera, which produces images that provide information about the organ function and composition.

Radiation Therapy

The primary objective of radiation therapy is to deliver an accurately prescribed dose of radiation to the target site while minimizing the radiation dose to surrounding healthy tissue. Radiation therapy can be used to treat cancer or to relieve symptoms associated with certain diseases, such as cancer. Treatments often involve multiple exposures spaced over a period of time for maximum therapeutic effect. When used to treat malignant diseases, radiation therapy is often delivered in combination with surgery or chemotherapy.

There are three main categories of radiation therapy:

1. External beam therapy (also called teletherapy) is a beam of radiation directed to the target tissue. There are several different categories of external beam therapy units. The

type of treatment machine that is regulated by the NRC contains a high-activity radioactive source (usually cobalt-60) that emits photons to treat the target site.

2. In brachytherapy treatments, sealed radioactive sources are permanently or temporarily placed near or on a body surface, in a body cavity, directly on a surface within a cavity, or directly on the cancerous tissue. The radiation dose is delivered at a distance of up to an inch (a few centimeters) from the target area.
3. Therapeutic radiopharmaceuticals are quantities of unsealed radioactive materials that localize in a specific region or organ system to deliver a large radiation dose.

Academic

The NRC issues licenses to academic institutions for educational and research purposes. For example, qualified instructors use radioactive materials in classroom demonstrations. Scientists in a wide variety of disciplines use radioactive materials for laboratory research.

INDUSTRIAL

The NRC and Agreement States license users of radioactive material for the specific type, quantity, and location of material that may be used. Radionuclides are used in industrial and commercial applications, including industrial radiography, gauges, well logging, and manufacturing. For example, radiography uses radiation sources to find structural defects in metallic materials and welds. Gas chromatography uses low-energy

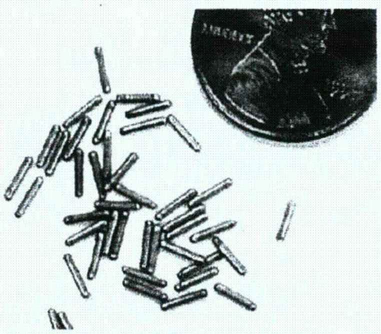


Photo courtesy: Oak Ridge Associated Universities

Iodine-125 and palladium-103 found in implantable seeds are primarily used to treat prostate cancer.

radiation sources for identifying the chemical elements in an unknown substance. Gas chromatography can determine the components of complex mixtures, such as petroleum products, smog, and cigarette smoke, and can be used in biological and medical research to identify the components of complex proteins and enzymes. Well-logging devices use a radioactive source and detection equipment to make a record of geological formations down a bore hole. This process is used extensively for oil, gas, coal, and mineral exploration.

Nuclear Gauges

Nuclear gauges are used as nondestructive devices to measure the physical properties of products and industrial processes as a part of quality control. Gauges use radiation sources to determine the thickness of paper products, fluid levels in oil and chemical tanks, and the moisture and density of soils and material at construction sites. There are fixed and portable gauges.

A fixed gauge consists of a radioactive source that is contained in a source

holder. When the user opens the container's shutter, a controlled beam of radiation hits the material or product being processed or controlled. A detector mounted opposite the source measures the radiation passing through the product. The gauge readout or computer monitor shows the measurement. The material and process being monitored dictate the selection of the type, energy, and strength of radiation.

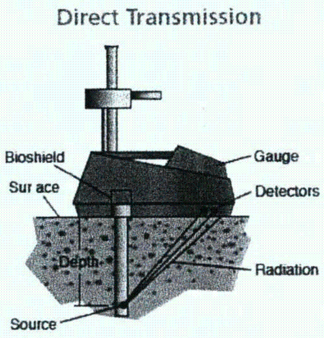
Fixed fluid gauges are installed on a pipe that is used by the beverage, food, plastics, and chemical industries to measure the densities, flow rates, levels, thicknesses, and weights of a wide variety of materials and surfaces.

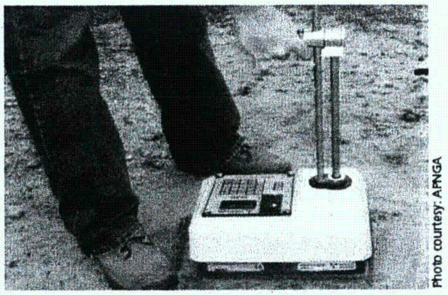
Figure 31 shows a portable gauge configuration in which the gamma source is placed under the surface of the ground through a tube. Radiation is then transmitted directly to the detector on the bottom of the gauge, allowing accurate measurements of compaction. Industry uses such gauges to monitor the structural integrity of roads, buildings, and bridges and to explore for oil, gas, and minerals. Airport security uses nuclear gauges to detect explosives in luggage at airports.

A portable gauge is a radioactive source and detector mounted together in a portable shielded device. The device is placed on the object to be measured, and the source is either inserted into the object or the gauge relies on a reflection of radiation from the source to bounce back to the bottom of the gauge. The detector in the gauge measures the radiation either directly from the inserted source or from the reflected radiation.

The radiation measurement indicates the thickness, density, moisture content, or some other property that is displayed on a gauge readout or on a computer monitor. The top of the gauge has sufficient shielding to protect the operator while the source is exposed. When the measuring process is completed, the source is retracted or a shutter closes, minimizing exposure from the source.

Figure 31. Moisture Density Gauge

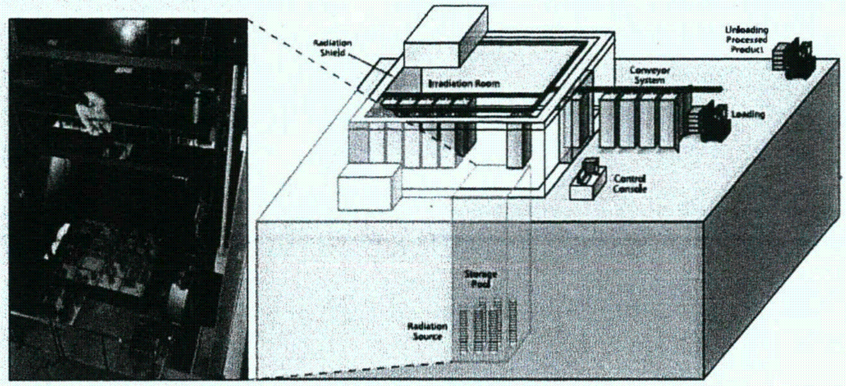




A moisture density gauge indicates whether a foundation is suitable for constructing a building or roadway.

Figure 32. Commercial Irradiator

Photo courtesy: Nordion



Commercial Irradiators

Commercial irradiators expose products such as food, food containers, spices, medical supplies, and wood flooring to radiation to eliminate harmful bacteria, germs, and insects or for hardening or other purposes (see Figure 32). The gamma radiation does not leave any radioactive residue or cause any of the treated products to become radioactive themselves. The source of that radiation can be radioactive materials (e g., cobalt-60), an x-ray tube, or an electron beam.

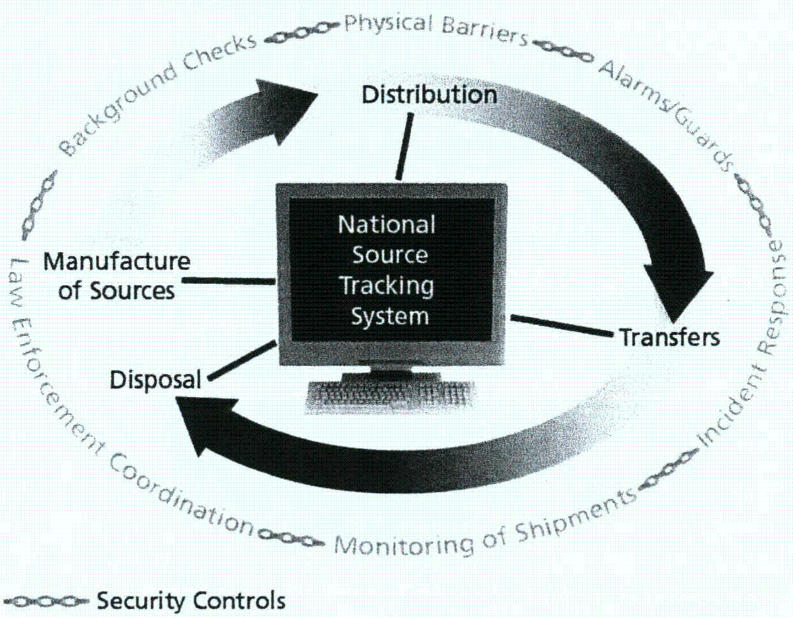
The NRC and Agreement States license approximately 50 commercial irradiators nationwide. For the past 40 years, the U.S. Food and Drug Administration and other agencies have approved the irradiation of meat and poultry as well as other foods, including fresh fruits, vegetables, and spices. The amount of radioactive material in the devices can range from 1 curie to 10 million curies. NRC regulations protect workers and the public from radiation involved in irradiation operations.

Generally, two types of commercial irradiators are in operation in the United States: underwater and wet-source-storage panoramic models.

In the case of underwater irradiators, the sealed sources (radioactive material encased inside a capsule) that provide the radiation remain in the water at all times, providing shielding for workers and the public. The product to be irradiated is placed in a watertight container, lowered into the pool, irradiated, and then removed.

With wet-source-storage panoramic irradiators, the radioactive sealed sources are also stored in the water, but they are raised into the air to irradiate products that are automatically moved in and out of the room on a conveyor system. Sources are then lowered back to the bottom of the pool. For this type of irradiator, thick concrete walls or steel barriers protect workers and the public when the sources are lifted from the pool.

Figure 33. Life Cycle Approach to Source Security



TRANSPORTATION

About 3 million packages of radioactive materials are shipped each year in the United States, either by road, rail, air, or water. This represents less than 1 percent of the Nation's yearly hazardous material shipments. Regulating the safety of commercial radioactive material shipments is the joint responsibility of the NRC and the U.S. Department of Transportation (DOT).

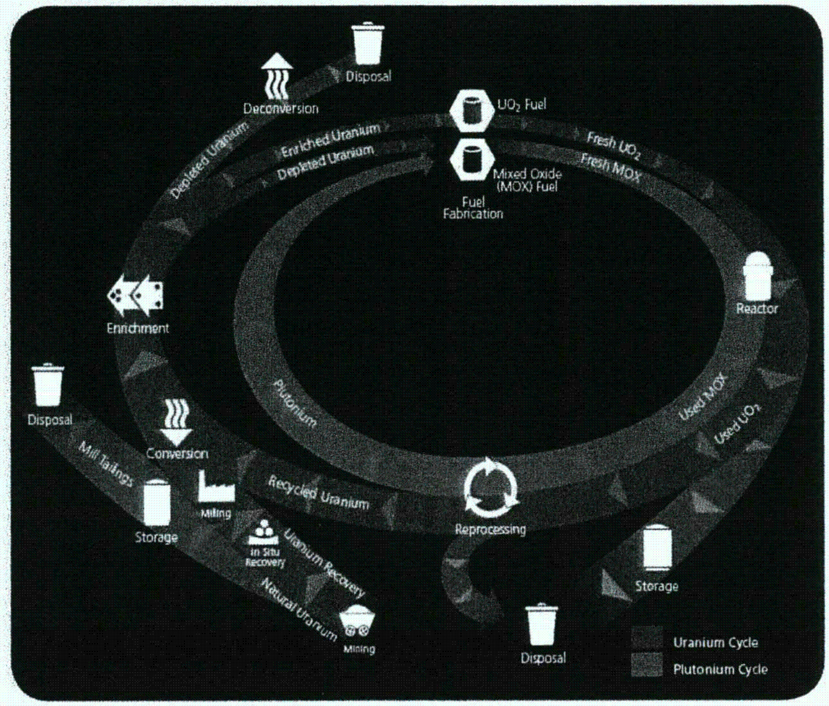
The vast majority of these shipments consist of small amounts of radioactive materials used in industry, research, and medicine. The NRC requires such materials to be shipped in accordance with DOT's hazardous materials transportation safety regulations.

MATERIAL SECURITY

In January 2009, the NRC deployed its National Source Tracking System (NSTS), by which the agency and its Agreement States track the manufacture, distribution, and ownership of the most high-risk sources. Licensees use the NSTS, a secure Web-based system, to enter up-to-date information on the receipt or transfer of tracked radioactive sources (see Figure 33).

Over the past several years, the NRC and the Agreement States have increased the controls they have imposed on the most sensitive radioactive materials, including physical security requirements and limited personnel access to the materials.

Figure 34. The Nuclear Fuel Cycle



Working with other Federal agencies, such as DHS, the NRC has also implemented a voluntary program of additional security improvements. Together, these activities help make potentially dangerous radioactive sources even more secure and less vulnerable to terrorists.

Principal Licensing and Inspection Activities

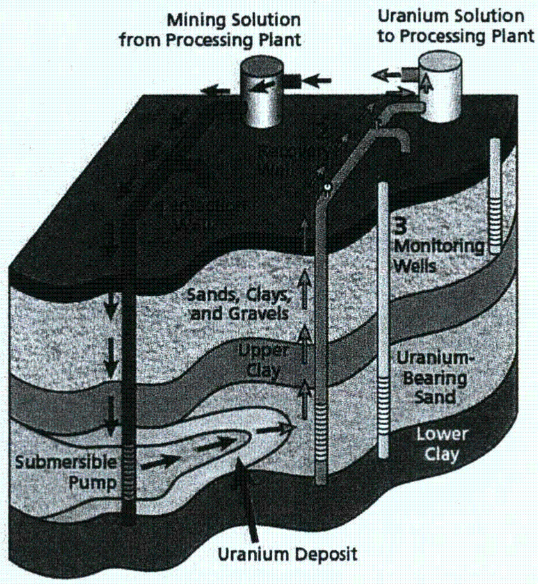
Each year, the NRC issues approximately 2,700 new licenses, license renewals, and amendments for existing material licenses.

The NRC conducts approximately 1,250 health and safety and security inspections of its nuclear materials licensees each year.

URANIUM RECOVERY

Figure 34 illustrates the nuclear fuel cycle, which begins with the uranium recovery, conversion, enrichment, and fabrication facilities that produce nuclear fuel for power plants. To make fuel for reactors, uranium is recovered or extracted from the ore, converted, enriched, and manufactured into fuel pellets.

Figure 35. The In Situ Uranium Recovery Process



Injection wells (1) pump a chemical solution—typically sodium bicarbonate, hydrogen peroxide, and oxygen—into the layer of earth containing uranium ore. The solution dissolves the uranium from the deposit in the ground and is then pumped back to the surface through recovery wells (2) and sent to the processing plant to be converted into uranium yellowcake. Monitoring wells (3) are checked regularly to ensure that uranium and chemicals are not escaping from the drilling area.

The NRC does not regulate traditional mining, but it does regulate the processing of uranium ore. It has jurisdiction over uranium recovery facilities such as conventional mills and in situ recovery (ISR) facilities.

The NRC has a well-established regulatory framework for ensuring that uranium recovery facilities are appropriately licensed, operated, decommissioned, and monitored to protect public health and safety.

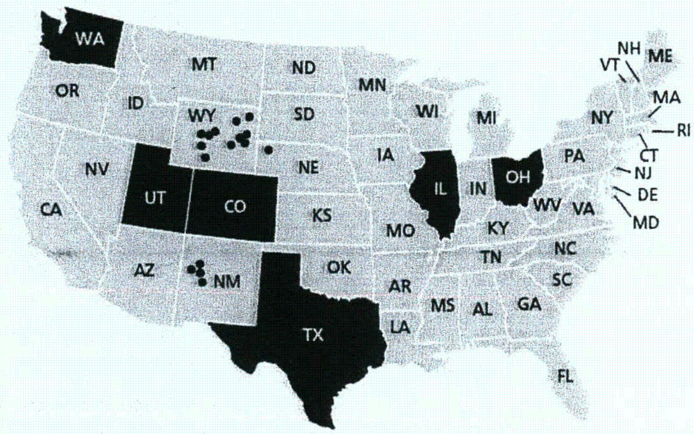
Conventional Uranium Mill

A conventional uranium mill is a chemical plant that extracts uranium from mined ore. Conventional mills are typically located in areas of low population density, within about 50 kilometers (30 miles) of a uranium mine. The mined ore is transported to the mill, where it is crushed. Sulfuric acid then dissolves the soluble components, including 90 to 95 percent of the uranium, from the ore. The uranium is then separated from the solution, concentrated, and dried to form yellowcake (yellow uranium oxide powder). There are 16 uranium recovery sites licensed by the NRC. Of these, 10 are in various stages of decommissioning and one is in standby status with the potential to restart in the future.

In Situ Recovery

ISR is another means of extracting uranium—this time from underground ore. ISR facilities recover uranium from ores for which recovery may

Figure 36. Locations of NRC-Licensed Uranium Recovery Facility Sites



- ● NRC-licensed uranium recovery facility sites (16)
- ■ States with authority to license uranium recovery facility sites
- States where the NRC has retained authority to license uranium recovery facilities

Table 9. Locations of NRC-Licensed Uranium Recovery Facilities

Licensee	Site Name, Location
In Situ Recovery Facilities	
Uranium One	Willow Creek, WY
Crow Butte Resources, Inc.	Crow Butte, NE*
Hydro Resources, Inc.°	Crownpoint, NM
Power Resources, Inc.	Smith Ranch and Highlands, WY*
Uranium One	Moore Ranch, WY
Conventional Uranium Mill Recovery Facilities	
American Nuclear Corp.†	Gas Hills, WY
Bear Creek Uranium Co.†	Bear Creek, WY
Exxon Mobil Corp.†	Highlands, WY
Homestake Mining Co.†	Homestake, NM
Kennecott Uranium Corp.°	Sweetwater, WY
Pathfinder Mines Corp.†	Lucky Mc, WY
Pathfinder Mines Corp.†	Shirley Basin, WY
Rio Algom Mining, LLC†	Ambrosia Lake, NM
Umetco Minerals Corp.†	Gas Hills, WY
United Nuclear Corp.†	Church Rock, NM
Western Nuclear, Inc.†	Split Rock, WY

Note: For further details on NRC-related uranium recovery facility applications in review and applications, restarts, and expansions, see the Web Link Index. This table does not include uranium recovery facilities licensed by Agreement States.

* Satellite facilities are located within the State.
† These sites are undergoing decommissioning.
° Kennecott has an operating license but is in "standby" mode. Hydro has an operating license, but the facility has not yet been constructed.

NUCLEAR MATERIALS

not be economically viable by other methods. In this process, a solution of native ground water typically mixed with oxygen or hydrogen peroxide and sodium bicarbonate or carbon dioxide is injected through wells into the ore to dissolve the uranium. The resulting solution is pumped from the rock formation, and the uranium is then separated from the solution to form yellowcake (see Figure 35). The United States has about 12 such ISR facilities. Of these facilities, the NRC licenses five, and Agreement States license the rest (see Figure 36 and Table 9).

Because of the resurgence of interest in the construction of new nuclear power plants, the agency anticipates as many as 27 applications for new uranium recovery facilities and expansions or restarts of existing facilities in the next few years. As of March 2011, the agency received seven applications for new facilities and four applications to expand or restart an existing facility. The current status of applications can be found on the NRC's Web site (see the Web Link Index). Existing facilities and new potential sites are located in Wyoming, New Mexico, Nebraska, South Dakota, and Nevada, and in the Agreement States of Texas, Colorado, and Utah (see Figure 37 and Table 10). The NRC works closely with stakeholders, including Native American Tribal governments, to address concerns with the licensing of new uranium recovery facilities.

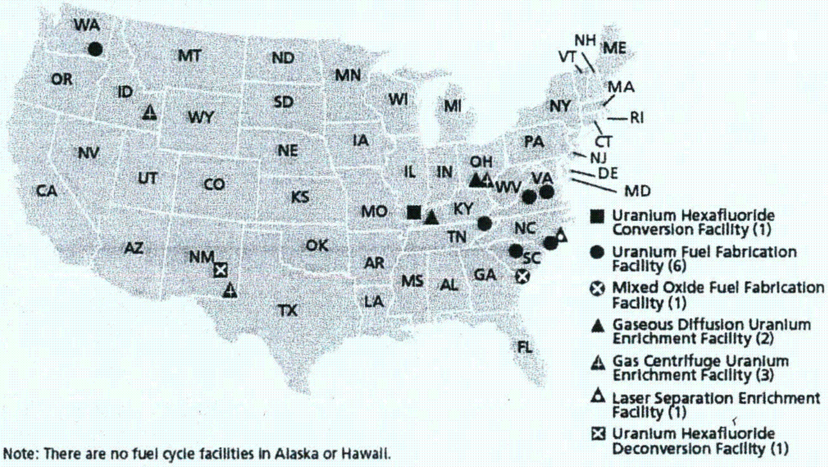
The NRC is also responsible for the following:

- inspecting and overseeing both active and inactive uranium recovery facilities
- ensuring that siting and design features of mill tailings (waste) minimize the release of radon and the disturbance of tailings by natural forces (see Glossary)
- developing requirements to ensure cleanup of active and formerly active uranium recovery facilities
- formulating stringent financial requirements to ensure funds are available for decommissioning
- monitoring adherence to requirements for below-grade disposal of mill tailings and liners for tailings impoundments
- monitoring to prevent ground water contamination
- long-term monitoring and oversight of decommissioned facilities

FUEL CYCLE FACILITIES

Special fuel facilities use a process that turns uranium from the ground into fuel for nuclear reactors. This process converts uranium yellowcake into uranium hexafluoride (UF_6), enriches the uranium in the isotope uranium-235, and fabricates ceramic fuel pellets. The NRC licenses and routinely conducts safety, safeguards, and environmental protection inspections at all commercial fuel cycle facilities involved in conversion, enrichment, and fuel fabrication (see Figures 37–40).

Figure 37. Locations of Fuel Cycle Facilities



Note: There are no fuel cycle facilities in Alaska or Hawaii.

Table 10. Major U.S. Fuel Cycle Facility Sites

Licensee	Location	Status
Uranium Hexafluoride Conversion Facility		
Honeywell International, Inc.	Metropolis, IL	active
Uranium Fuel Fabrication Facilities		
Global Nuclear Fuels-Americas, LLC	Wilmington, NC	active
Westinghouse Electric Company, LLC Columbia Fuel Fabrication Facility	Columbia, SC	active
Nuclear Fuel Services, Inc.	Erwin, TN	active
AREVA NP, Inc. Mt. Athos Road Facility	Lynchburg, VA	inactive—possession only
B&W Nuclear Operations Group	Lynchburg, VA	active
AREVA NP, Inc.	Richland, WA	active
Mixed Oxide Fuel Fabrication Facility		
Shaw AREVA MOX Services, LLC	Aiken, SC	in construction, operating license under review
Gaseous Diffusion Uranium Enrichment Facilities		
USEC Inc.	Paducah, KY	active
USEC Inc.	Piketon, OH	in cold shutdown*
Gas Centrifuge Uranium Enrichment Facilities		
USEC Inc.	Piketon, OH	in construction
Louisiana Energy Services (URENCO-USA)	Eunice, NM	active**
AREVA Enrichment Services	Idaho Falls, ID	under review
Laser Separation Enrichment Facility		
GE-Hitachi	Wilmington, NC	under review
Uranium Hexafluoride Deconversion Facility		
International Isotopes	Hobbes, NM	under review

* Currently in cold shutdown and in process of decertification and not used for enrichment.

** Partially operating and producing enriched uranium while undergoing further phases of construction.

Note: The NRC regulates nine other facilities that possess significant quantities of special nuclear material (other than reactors) or process source material (other than uranium recovery facilities). Data as of April 2011.

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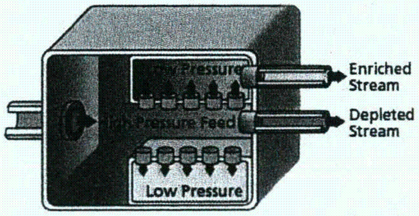
Figure 38. Enrichment Processes

A. Gaseous Diffusion Process



A. The gaseous diffusion process uses molecular diffusion to separate a gas from a two-gas mixture. The isotopic separation is accomplished by diffusing uranium, which has been combined with fluorine to form UF_6 gas, through a porous membrane (barrier) and using the different molecular velocities of the two isotopes to achieve separation.

B. The gas centrifuge process uses a large number of rotating cylinders in series and parallel configurations. Gas is introduced and rotated at high speed, concentrating the component of higher molecular weight toward the outer wall of the cylinder and the component of lower molecular weight toward the center. The enriched and the depleted gases are removed by scoops.

B. Gas Centrifuge Process

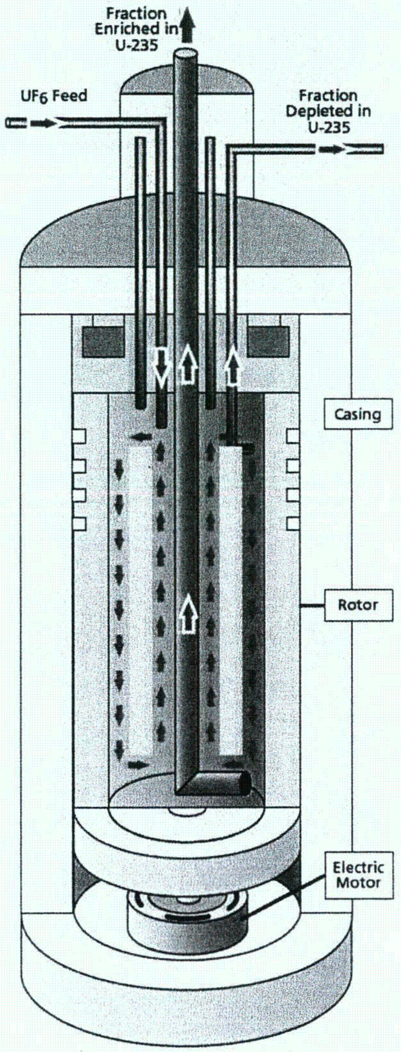
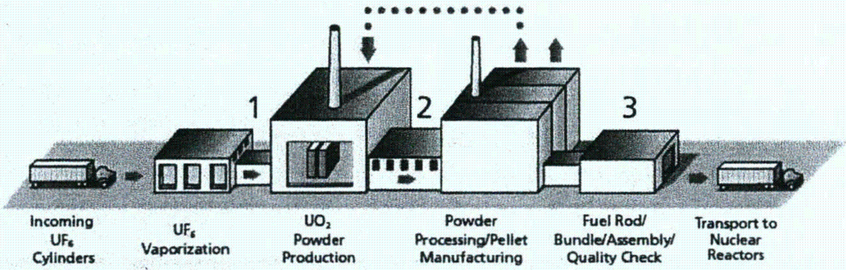
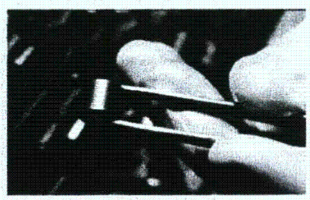


Figure 39. Simplified Fuel Fabrication Process

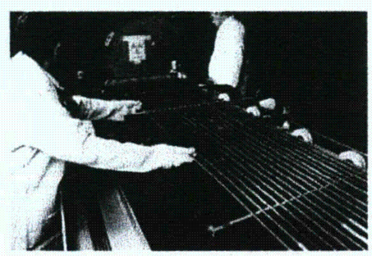


Fabrication of commercial light-water reactor fuel consists of the following three basic steps:
(1) the chemical conversion of UF_6 to UO_2 powder
(2) a ceramic process that converts UO_2 powder to small ceramic pellets
(3) a mechanical process that loads the fuel pellets into rods and constructs finished fuel assemblies

Figure 40. Fuel Pellets



(Left) Small ceramic fuel pellets. (Right) Fuel pellets being assembled into fuel rods.



On average, the NRC completes approximately 85 new licenses, license renewals, license amendments, and safety and safeguards reviews for fuel cycle facilities annually.

Fabrication is the final step in the process used to produce uranium fuel. Fuel fabrication facilities mechanically and chemically process the enriched uranium into nuclear reactor fuel.

Fabrication begins with the conversion of enriched UF_6 gas to a uranium dioxide (UO_2) solid. Nuclear fuel is made to maintain both its chemical and physical properties under the extreme conditions of heat and radiation present inside an operating reactor vessel. After the UF_6 is chemically converted to UO_2, the powder is blended, milled, pressed, and fused into ceramic fuel pellets about the size of a fingertip. The pellets are stacked into tubes about 14 feet (2.6 meters) long made of material called "cladding" (such as zirconium alloys) (see Figure 40). After careful inspection, the resulting fuel rods are bundled into fuel assemblies for use in reactors. The assemblies are washed, inspected, and stored in a special rack until ready for shipment to a nuclear power plant site. The NRC inspects this operation at every step of the process.

Domestic Safeguards Program

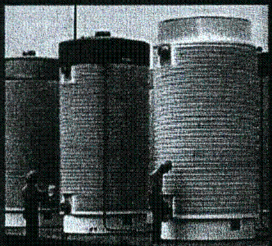
The NRC's domestic safeguards program for fuel cycle facilities and transportation is aimed at ensuring that special nuclear material (such as plutonium or enriched uranium) is not stolen for possible malevolent uses. The program also works to ensure that such material does not pose an unreasonable risk to the public from sabotage or terrorism.

The NRC verifies through licensing and inspection activities that licensees apply safeguards to protect special nuclear material. Additionally, the NRC and DOE developed the Nuclear Materials Management and Safeguards System (NMMSS) to track transfers and inventories of special nuclear material, source material from abroad, and other material.

The NRC has issued licenses to approximately 180 facilities authorizing them to possess special nuclear material in quantities ranging from a single kilogram to multiple tons. These licensees verify and document their inventories in the NMMSS database. The NRC or State governments license several hundred additional sites that possess special nuclear material in smaller quantities (typically ranging from 1 gram to tens of grams).

Licensees that possess small amounts of special nuclear material are now required to confirm their inventory annually in the NMMSS database. Previously, those licensees reported transfers of material but not annual inventories.

RADIOACTIVE WASTE



Top: Dry cask storage of spent nuclear fuel.

Middle: Spent fuel pool at a research and test reactor. (Photo courtesy: University of Wisconsin-Madison)

Bottom: NRC inspectors examine a container to determine if it meets NRC standards.

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 onsite 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.

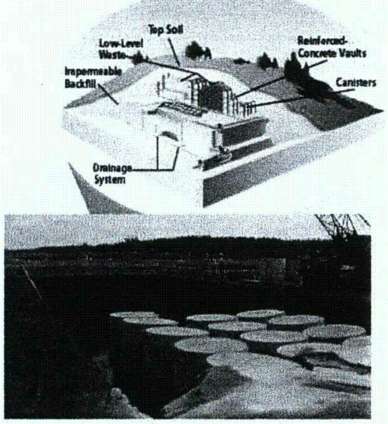
Commercial LLW is disposed of in facilities licensed by either the NRC or Agreement States in accordance with health and safety requirements. The facilities are designed, constructed, and operated to meet safety standards. The operator of the facility also extensively characterizes the site on which 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 41).

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—Class 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.

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:

Figure 41. Low-Level Waste Disposal



This LLW disposal site accepts waste from the compact States.

- Form regional compacts, with each compact to provide for LLW disposal site access (see Table 11).
- Manage LLW import to, and export from, a compact.

Exclude waste generated outside a compact.

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 and Rocky Mountain Compacts. 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 expected to begin receiving LLW in late 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

Table 11. U.S. Low-Level Radioactive Waste Compacts

Appalachian	**Northwest**	**Southwestern**
Delaware	Alaska	Arizona
Maryland	Hawaii	California
Pennsylvania	Idaho	North Dakota
West Virginia	Montana	South Dakota
Atlantic	Oregon	**Texas**
Connecticut	Utah*	Texas
New Jersey	Washington*	Vermont
South Carolina*	Wyoming	**Unaffiliated**
Central	**Rocky Mountain**	District of Columbia
Arkansas	Colorado	Maine
Kansas	Nevada	Massachusetts
Louisiana	New Mexico	Michigan
Oklahoma	*(Northwest accepts Rocky Mountain waste as agreed between compacts)*	Nebraska
Central Midwest	**Southeast**	New Hampshire
Illinois	Alabama	New York
Kentucky	Florida	North Carolina
Midwest	Georgia	Puerto Rico
Indiana	Mississippi	Rhode Island
Iowa	Tennessee	
Minnesota	Virginia	
Missouri		
Ohio		
Wisconsin		

Note: Data as of June 2011.
*Site of an active LLW disposal facility.

RADIOACTIVE WASTE

HIGH-LEVEL RADIOACTIVE WASTE MANAGEMENT

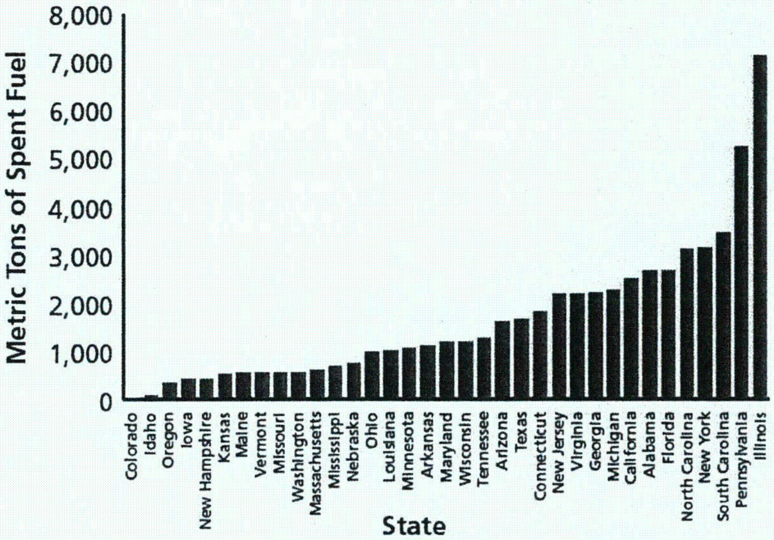
Spent Nuclear Fuel Storage

Commercial spent nuclear fuel, although highly radioactive, is stored safely and securely in 35 States (see Figure 42). This includes 31 States with operating nuclear power reactors, where spent fuel is safely stored onsite 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 2011, the amount of commercial spent fuel in safe storage at commercial nuclear power plants was an estimated 63,000 metric tons. The amount of spent fuel in storage at individual 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.

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 expected

Figure 42. Storage of Commercial Spent Fuel by State through 2011



Note: Idaho is holding used fuel from Three Mile Island, Unit 2. Data are rounded up to the nearest 10 tons.
Source: ACI Nuclear Energy Solutions and U.S. Department of Energy (updated May 2011)

to send the spent fuel to a recycling plant. However, the Federal Government declared a moratorium on recycling spent fuel in 1977. 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 43). 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 44).

Currently, there are 63 licensed ISFSIs in the United States. As of 2011, NRC-licensed ISFSIs were storing spent fuel in over 1,220 loaded dry casks (see Figure 45).

The NRC authorizes storage of spent fuel at an ISFSI under two licensing options:

1. site-specific licensing

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 onsite 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.

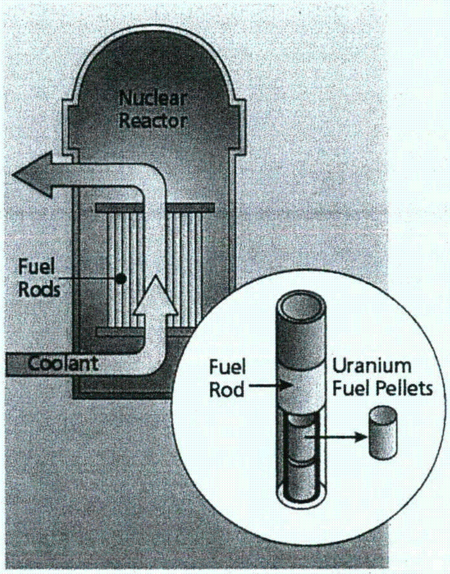
See Appendix H for a list of dry spent fuel storage systems that are approved for use with a general license. See Appendix I for a list of dry spent fuel storage licensees.

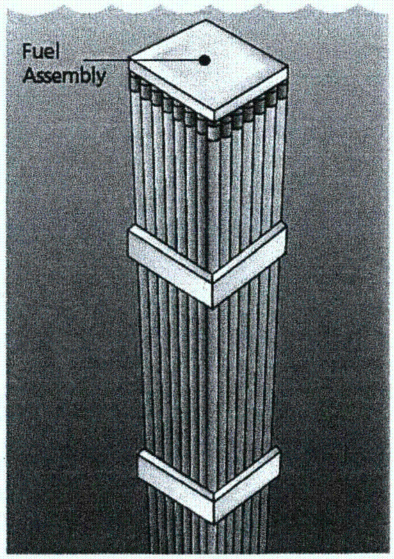
No more than 30 days before the certificate expiration date, the cask vendor may apply for renewal. If the cask vendor does not apply for renewal, a general licensee may apply for renewal.

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.

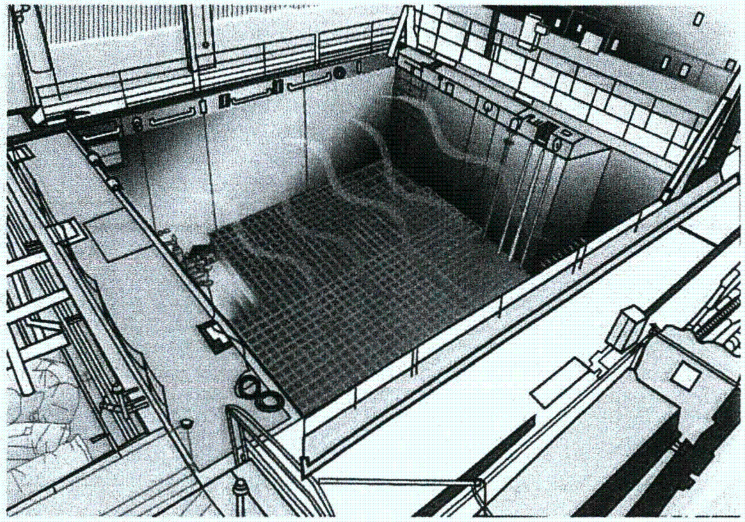
Figure 43. Spent Fuel Generation and Storage after Use

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.*

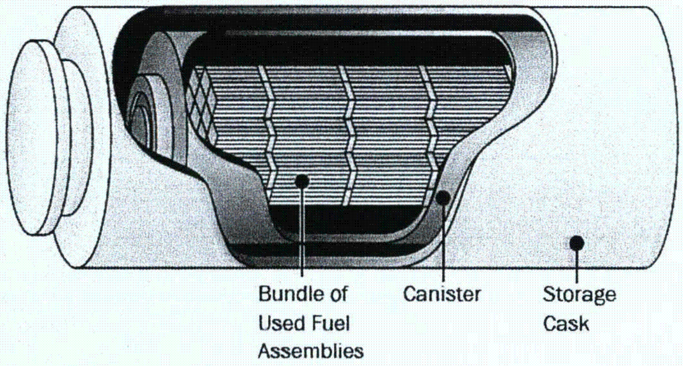




2 *After about 6 years, spent fuel assemblies—typically 14 feet (4.3 meters) long and containing nearly 200 fuel rods for PWRs and 80–100 fuel rods for BWRs—are removed from the reactor and allowed to cool in storage pools for a few years. At this point, the 900-pound (409-kilogram) assemblies contain 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 44) or transported off site to a high-level radioactive waste disposal site.*



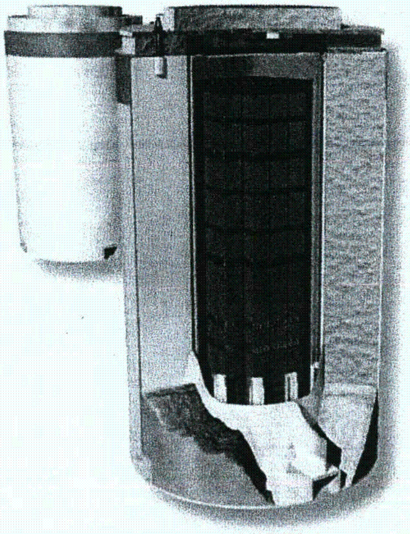
Source: DOE and the Nuclear Energy Institute

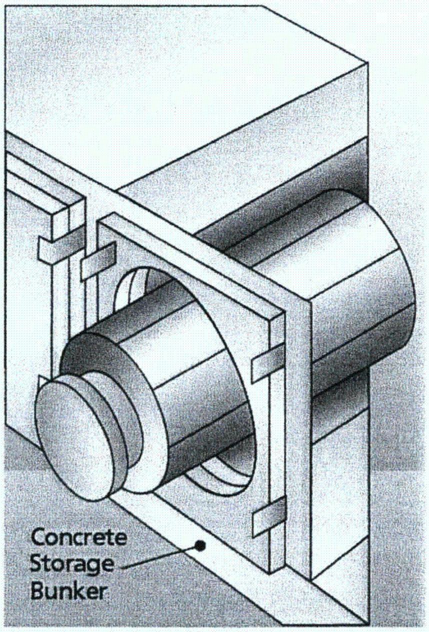
RADIOACTIVE WASTE

Figure 44. Dry Storage of Spent Nuclear Fuel

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

1 Once the spent fuel has 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.

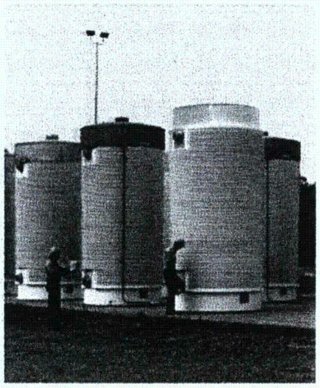
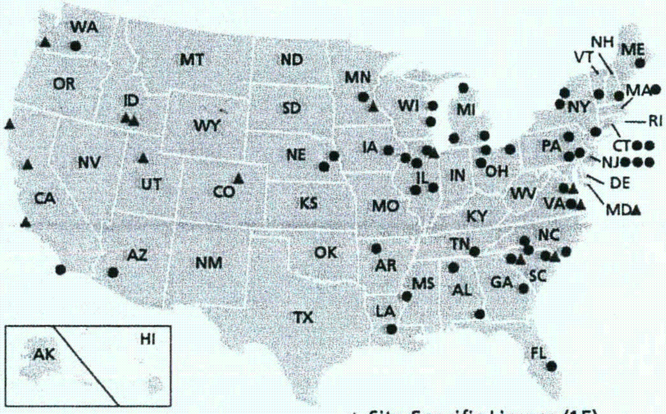


Figure 45. Licensed/Operating Independent Spent Fuel Storage Installations by State



▲ Site-Specific License (15)
● General License (48)

33 States have at least one ISFSI

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

GEORGIA
- ● Hatch

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

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

IOWA
- ● Duane Arnold

LOUISIANA
- ● River Bend

MAINE
- ● Maine Yankee

MARYLAND
- ▲ Calvert Cliffs

MASSACHUSETTS
- ● Yankee Rowe

MICHIGAN
- ● Big Rock Point
- ● Fermi
- ● 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
- ● Perry

OREGON
- ▲ Trojan

PENNSYLVANIA
- ● Limerick
- ● Susquehanna
- ● Peach Bottom

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

TENNESSEE
- ● Sequoyah

UTAH
- ▲ Private Fuel Storage

VERMONT
- ● Vermont Yankee

VIRGINIA
- ● ▲ Surry
- ● ▲ North Anna

WASHINGTON
- ● Columbia

WISCONSIN
- ● Point Beach
- ● Kewaunee

Note: Data are current as of June 2011.
NRC-abbreviated unit names used.

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.

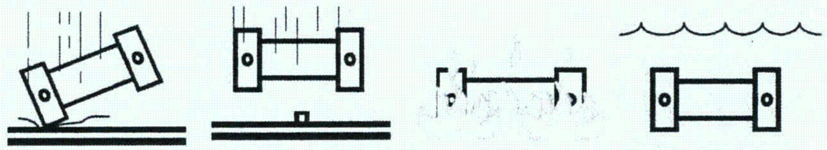
DOE submitted its license application to the NRC on June 3, 2008, for Yucca Mountain in Nevada. The NRC formally accepted it for review in September 2008 and began the detailed technical review and associated adjudicatory activities. In 2009, President Barack Obama announced that the administration would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

On January 29, 2010, the President created the Blue Ribbon Commission on America's Nuclear Future to reassess the national policy on high-level waste disposal. The task of the Blue Ribbon Commission is to "conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle." In light of these developments, the NRC began reassessing its management of spent fuel regulations to position the agency to adapt quickly to changes in national policy. The three key areas in this effort are the nuclear fuel cycle, spent fuel storage and transportation, and high-level waste disposal.

Recycling

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

Figure 46. 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.

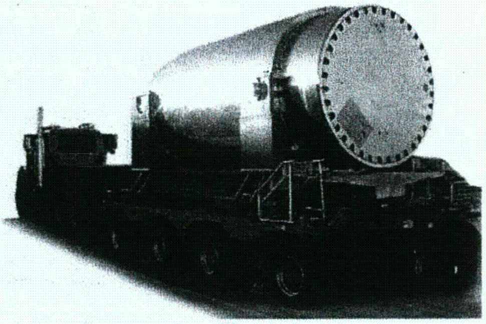
countries reprocess their spent nuclear fuel to recover fissile material and use it to generate more energy. Although the NRC has not received an application for a reprocessing facility, the agency has completed an initial analysis of the existing regulatory framework in preparation for such an application. The NRC is developing the technical basis for a possible revision of the regulations 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.
- 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 46).



Empty storage transport container on a semi tractor-trailer rig.

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 20 dry storage and transport package licensees.
- 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).

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.

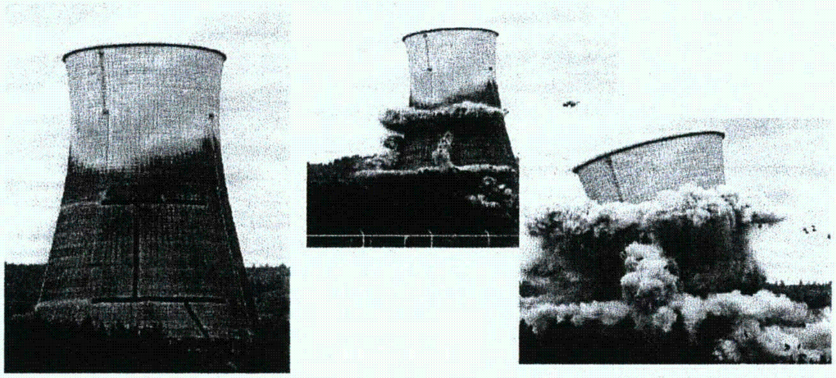
The NRC regulates the decontamination and decommissioning of materials and fuel cycle facilities, nuclear power plants, research and test reactors, and uranium recovery facilities, with the ultimate goal of license termination. The NRC terminates approximately 200 materials licenses each year. Most of 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 47).

As of early 2011, the following facilities were undergoing decommissioning under NRC jurisdiction:

- 13 nuclear power early demonstration reactors
- 12 research and test reactors
- 20 complex decommissioning materials facilities (see Table 12)
- 1 fuel cycle facility
- 11 uranium recovery facilities

See Appendices B and F for lists of permanently shut down nuclear reactors and nuclear power, research, and test reactors undergoing decommissioning.

The "Status of the Decommissioning Program 2010 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.

Figure 47. Locations of NRC-Regulated Complex Material Sites Undergoing Decommissioning

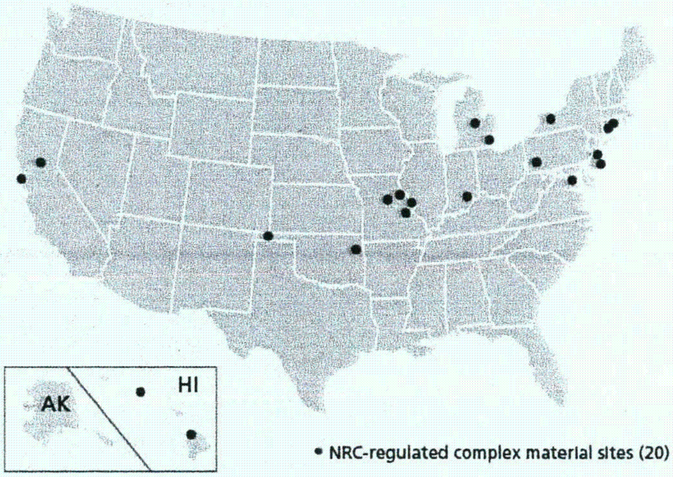


Table 12. NRC-Regulated Complex Material Sites Undergoing Decommissioning

Company	Location
AAR Manufacturing, Inc. (Brooks & Perkins)	Livonia, MI
ABB, Inc.	Windsor, CT
Analytical Bio-Chemistry Laboratories	Columbia, MO
Army, Department of, Jefferson Proving Ground	Madison, IN
Babcock & Wilcox SLDA	Vandergrift, PA
Beltsville Agricultural Research Center	Beltsville, MD
FMRI	Muskogee, OK
Hunter's Point Naval Shipyard	San Francisco, CA
Kerr-McGee	Cimarron, OK
Mallinckrodt Chemical, Inc.	St. Louis, MO
McClellan Air Force Base	Sacramento, CA
NWI Breckenridge	Breckenridge, MI
Pohakuloa Training Area	Kawaihe Harbor, HI
Shieldalloy Metallurgical Corp.	Newfield, NJ
Schofield Army Barracks	Wahiawa, HI
Sigma Aldrich	Maryland Heights, MO
Stepan Chemical Corporation	Maywood, NJ
UNC Naval Products	New Haven, CT
West Valley Demonstration Project	West Valley, NY
Westinghouse Electric Corporation—Hematite	Festus, MO

Note: Data as of July 2011.

RADIOACTIVE WASTE

SECURITY AND EMERGENCY PREPAREDNESS

Top: Nuclear power plant security officers don special equipment for a mock attack drill.

Middle: The Commissioners listen as NRC Executive Director for Operations Bill Borchardt gives a briefing on the agency's response to the recent nuclear events in Japan.

Bottom: The NRC Headquarters Operations Center during an emergency preparedness exercise.

OVERVIEW

Nuclear security is a high priority for the NRC. For the past several decades, effective NRC regulation and strong partnerships with a variety of Federal, State, Tribal, and local authorities have ensured effective implementation of security programs at nuclear power plants across the country. In fact, nuclear power plants are likely the best protected private sector facilities in the United States. However, given today's threat environment, the agency recognizes the need for continued vigilance and high levels of security.

In recent years, the NRC has made many enhancements to bolster the security of the Nation's nuclear facilities and radioactive materials. Because nuclear power plants are inherently robust structures, these additional security upgrades largely focus on the following improvements:

- well-trained and armed security officers
- high-tech equipment and physical barriers
- greater standoff distances for vehicle checks
- intrusion detection and surveillance systems
- tested emergency preparedness and response plans
- restrictive site access control, including background checks and fingerprinting of workers

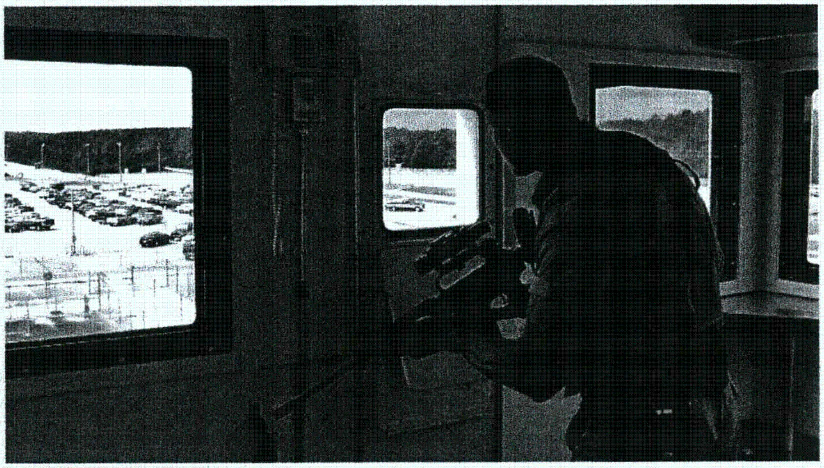
Additional layers of security are provided by coordinating and sharing threat information among DHS, the U.S. Federal Bureau of Investigation, intelligence agencies, the U.S. Department of Defense, and local law enforcement.

FACILITY SECURITY

Nuclear power plants and Category I fuel facilities must be able to defend successfully against a set of hypothetical threats that the agency calls the design-basis threat (DBT). This includes threats that challenge a plant's physical security, personnel security, and cyber security. The NRC does not make details of the DBT public because of security concerns. However, the agency continuously evaluates this set of hypothetical threats against real-world intelligence to ensure that the DBT remains current.

To test the adequacy of a nuclear power plant's defenses against the DBT, the NRC conducts rigorous "force-on-force" inspections. During these inspections, exercises are conducted in which a highly trained mock adversary force "attacks" a nuclear facility. Beginning in 2004, the NRC began conducting more challenging and realistic force-on-force exercises that also occur more frequently.

To ensure that facilities meet their security requirements, the NRC inspects nuclear power plants and fuel fabrication facilities, spending about 8,000 hours a year scrutinizing security (excluding force-on-force inspections). Publicly available portions of security-related inspection reports can be found on the NRC Web site (see the Web Link Index).



A well-trained and armed security officer at a nuclear power plant facility.

CYBER SECURITY

Nuclear facilities use digital and analog systems to monitor, control, and run various types of equipment and to obtain and store vital information. Protecting these systems and the information they contain from sabotage or malicious use is called "cyber security." All nuclear power plants licensed by the NRC must have a cyber security program. A new cyber security rule, issued in 2009, requires each nuclear power facility to submit a cyber security plan and implementation timeline for NRC approval. Once the licensee has fully implemented its program, the NRC will conduct a comprehensive inspection on site.

The NRC has formed a cyber security team that includes technology and threat experts who constantly evaluate and identify emerging cyber-related issues that could affect plant systems. This team makes recommendations to other NRC offices and programs on cyber security issues.

MATERIALS SECURITY

The security of radioactive materials is important for a number of reasons. For example, terrorists could use radioactive materials to make a radiological dispersal device such as a dirty bomb. The NRC works with its Agreement States, other Federal agencies, IAEA, and licensees to protect radioactive material from theft or diversion. The agency has made improvements and upgrades to the joint NRC-DOE database that tracks the movement and location of certain forms and quantities of special nuclear material. In early 2009, the NRC deployed its new NSTS, designed to track the most risk-sensitive sources on a continuous basis. Other improvements allow U.S. Customs and Border Protection agents to promptly validate whether radioactive materials coming into the United States are properly licensed by the NRC.

EMERGENCY PREPAREDNESS

Well-developed and practical emergency preparedness plans ensure that a nuclear power plant operator can protect public health and safety in the unlikely event of an emergency.

The NRC staff participates in emergency preparedness exercises, some of which include security- and terrorism-based scenarios. To form a coordinated system of emergency preparedness and response, as part of these exercises, the NRC works with licensees; Federal agencies; State, Tribal, and local officials; and first responders. This system includes public information, preparations for evacuation, instructions for sheltering, and other actions to protect the residents near nuclear power plants in the event of a serious incident.

As a condition of their license, operators of nuclear facilities develop and maintain effective emergency plans and procedures. The NRC inspects licensees to ensure that they are prepared to deal with emergencies. In addition, the agency monitors performance indicators related to emergency preparedness. (see Figure 48).

The NRC assesses the ability of nuclear power plant operators to respond to emergencies. For nuclear power plants, operators are required to conduct full-scale exercises with the NRC, the Federal Emergency Management Agency (FEMA), and State and local officials at least once every 2 years.

Figure 48. Industry Performance Indicators: Annual Industry Percentages, FYs 2001–2010—for 104 Plants

The percentage of ANS sirens that successfully operated during periodic tests in the previous year. The result is an indicator of the reliability of the ANS to alert the public in an emergency.