Backgrounder

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Research and Test Reactors

Background

Research and test reactors -- also called "non-power" reactors-- are nuclear reactors primarily used for research, training and development. These reactors contribute to almost every field of science including physics, chemistry, biology, medicine, geology, archeology, and environmental sciences.

The U.S. Nuclear Regulatory Commission (NRC) regulates approximately 50 research and test reactors; two thirds are currently operating and the remainder are in the process of either removing radioactive material from the facility (decommissioning), or awaiting decommissioning and have licenses only to possess residual radioactive material, not to operate the reactor. Most of these research and test reactors are at universities or colleges in the United States. The Department of Energy (DOE) regulates its own research/test reactors.

Regulatory Oversight

<u>Licensing</u>

The NRC licenses research and test reactors consistent with NRC regulations to ensure an acceptable level of safety. These licenses include authorization for operation and possession of radioactive material. To change license requirements, the NRC takes licensing actions that include:

- license renewals
- license extensions
- authorizations for decommissioning
- license terminations after completion of decommissioning
- conversions to low-enriched uranium fuel
- power upgrades
- technical specification changes

For certain technical issues and safety standards development, NRC coordinates with such organizations as the National Organization of Test, Research, and Training Reactors, the American Nuclear Society, and the International Atomic Energy Agency.

Inspection

NRC staff inspect each facility periodically to ensure that licensees operate their facilities in accordance with safety and security requirements specified in NRC regulations and reactor-specific license conditions. The NRC uses a graded approach in its inspection program, i.e., less frequent and detailed inspections at facilities that pose a lower risk.
There are two types of inspection programs for operating research and test reactors.

1) For reactors licensed to operate at power levels of 2 megawatts or greater, the inspection program is completed annually.

2) For reactors licensed to operate at power levels below 2 megawatts, the inspection program is completed every two years.

The inspection program for operating reactors includes review of:

- Organizational structure
- Reactor operator qualifications
- Design and design control
- Radiation and environmental protection
- Maintenance and surveillance activities
- Transportation
- Material control and accounting
- Operational activities
- Review and audit functions
- Experiments
- Fuel handling
- Procedural controls
- Emergency preparedness
- Security

Those reactors which are shut down and are not actively decommissioning have an abbreviated inspection program completed every three years. Inspections verify the condition of the reactor and nuclear materials on site. This inspection program includes a review of organization and staffing, review and audit functions, operator requalification, radiological surveys, surveillance, emergency preparedness, and other areas as needed.

Reactors that are in the process of decommissioning are inspected by the NRC for selected aspects of licensee’s safety programs and activities. This includes examination of: organization and staffing, work controls, radiation protection, plant discharge monitoring, plant configuration controls, audit programs, emergency preparedness, radioactive waste management, and transportation. Since 1958, NRC and its predecessor, the Atomic Energy Commission, have decommissioned 78 research and test reactors.

If the inspection program identifies violations of requirements, the NRC takes appropriate enforcement action. The NRC inspection program also includes following up on allegations of safety or regulatory concerns.

Operator Licensing

To be licensed, research and test reactor operators must have the required knowledge, skills and abilities to control the reactor during both routine operations and emergencies. As part of the initial operator licensing process, NRC prepares and administers both a comprehensive written examination and a hands-on operating test. These examinations are based on requirements in the Commission's regulations (10 CFR Part 55). The NRC issues six-year licenses to operators who successfully complete the examination process. An Individual is licensed to operate a reactor at a specific location and that the license is not portable. To operate a research reactor at another location, the individual must be trained on that reactor and pass another licensing examination.

Licensed operators are required to maintain their expertise through a Requalification Program, consisting of both refresher training on material covered during initial licensing and training on new or modified systems, procedures and programs. Operators must pass a comprehensive written test every two years and an annual operating tests, both of which are developed and administered by reactor management. NRC reviews these examinations as part of the inspection program and determines if the operator meets the Requalification Program requirements. Every six years operators are required to submit an application to renew their license. As part of the application, reactor management must certify satisfactory participation in the Requalification Program.

Security

All research and test reactors are designed and operated so that material is not easily handled or dispersed, thus protecting against potential radiological exposure or theft of material. These reactors have a limited amount of radioactive material on site and therefore pose a low risk from radiation and the theft of nuclear material. The NRC inspects the reactor’s security and emergency plans, as well as its operations and design to ensure protection of public health and safety. Security requirements are based on a graded approach with increasing requirements for material that is more attractive for theft or diversion and for facilities that have larger inventories of radiological material.

Prior to September 11, 2001, all reactors had security plans and emergency plans as required by NRC regulations. Following the terrorist attacks on 9/11, the NRC advised licensees to consider taking additional security measures. Later NRC imposed additional security measures on research and test reactors by Confirmatory Action Letter. While the specifics of these measures are not publicly available for security reasons, in general, they include:

- enhancements in screening of personnel,

- ☐ lock and key systems for controlling access to the facility,
- ☐ observation of activities within the facilities,
- ☐ alarms or other devices to detect unauthorized presence,
- ☐ operability of communication systems,
- ☐ vehicle and package searches, and
- ☐ heightened coordination with appropriate local, State, and Federal resources
- ☐ liaisons with the FAA and law enforcement authorities to report unusual overflights or potential threats.

NRC has evaluated security plans, procedures and systems and has verified, through inspection that appropriate security measures are in place to protect the reactors from theft or sabotage. The NRC continues to inspect research and test reactors to ensure compliance with all NRC regulations and protection of public health and safety. Further, NRC maintains regular communications with other Federal agencies such as the FBI and the Department of Homeland Security to assess potential threats to all classes of licensees including those of research and test reactors.

Research and Development Activities

The radiation produced by research reactors is the key output, not the very little amount of energy produced. The most common use of this radiation is for experiments. Primarily, two types of radiation are used from research reactors: neutrons and gamma rays. Some experiments require more of one type radiation than the other. The amount and types of radiation may be controlled by placing different types of "filters" between the reactor and the experiment, or positioning the experiment at different locations relative to the radioactive fuel in the core.

Experimenters use different types of facilities to expose the material to the required types of radiation. Experimental facilities include in-core radiation "baskets," pneumatic (air-operated) tubes (similar to systems used at drive-through banks), and beam tubes (holes in the shielding around the reactor which can direct a beam of radiation to the experiment). Radiation is used to study material characteristics that cannot be readily measured otherwise.

One widely used type of experiment is <u>neutron scattering</u>. Radiation from the reactor is directed at the material to be studied. The manner in which the radiation interacts and bounces off, or scatters, from the material yields information on structure and properties. Neutron scattering is an important tool in experiments dealing with superconductors, polymers, metals, and proteins. Researchers can analyze molecular structure, surfaces and interfaces, measure electronic and magnetic properties, stress and strain conditions, and gauge other characteristics.

<u>Neutron radiography</u> is another experimental technique. It is similar to medical or dental X-rays. These experiments are used to determine structural integrity for aerospace, automotive and medical components.

Neutron activation analysis is another powerful tool used in the detection of very small (trace) amounts of material. It is used to measure the presence of trace elements such as environmental pollutants in soil, water, air, and foods with an accuracy of several parts per billion. Neutron activation may also be used to create new radioactive isotopes such as radio-pharmaceuticals (radioactive material used in medicine) and to process silicon prior to use in computer chips.

Research and test reactors also are involved in medical research using neutrons for the treatment of cancerous tumors or making radioisotopes for research and therapy. In addition, materials used in power reactors are irradiated in research and test reactors to assess the change in characteristics from exposure to radiation. These changes are important in assessing safety functions and in considering license extension for nuclear power plants.

Research and Test Reactor Design and Safety Features

Research and test reactors have many varieties and forms. Reactors may be classified by the type of material used to slow down the neutrons which cause fission. Typical moderators include water (H_2O), heavy water (D_2O), polyethylene, and graphite.

Water moderated reactors, the predominant type of reactor licensed by NRC, can be further classified as either pool-type or tank-type. Pool-type reactors have a core immersed in an open pool of water. The pools typically have about 20 feet of water above the core to allow cooling and radiation shielding. At pool-type reactors, the operating core can be observed through the pool water. Tank-type reactors have a core that is in a tank with water, sealed at the top.

Reactors may also be classified by the type of fuel used, such as MTR (plate type fuel) or TRIGA fuel. TRIGA fuel is unique fuel in that a moderator (hydrogen) is chemically bonded to the fuel.

All NRC-licensed research and test reactors have a built-in safety feature, which reduces reactor power during potential accidents before an unacceptable power level or temperature could be reached.

Research and test reactors are typically licensed by NRC according to the total thermal (heat) energy produced by the reactor. These facilities range in size from 0.10 watt to 20 megawatts-thermal. In contrast, a typical commercial nuclear power reactor is rated at 3,000 megawatts-thermal. Because of this large difference in power generated, the consequence of an accident at a research and test reactor is limited when compared to a commercial power reactor. For this reason, emergency planning zones to protect the public from potential radiological accidents are well within owner-controlled areas, that are often the boundary of the room in which the reactor is housed.

All research and test reactors have radiation monitors with larger facilities having monitors which measure particulate and gaseous releases to the environment.

Unlike power plants, research and test reactor control rooms are usually in the confinement or containment area where the reactor is located. Facility staff and personnel work in the reactor room or building during operation. Most research and test reactors are in rooms or buildings that have a dedicated ventilation system and all have systems that control the release of radiation.

These reactors have fail-safe shutdown systems that monitor facility conditions, and before an unsafe condition occurs, control rods can be used to rapidly reduce the reactor power level. There are also redundant systems to shut down a reactor to provide added protection of the public.

Because of the low power levels at which research and test reactors operate, they require no or minimal cooling for short periods after shutdown. In addition, many of these reactors operate on a very limited schedule and have a limited amount of radioactive material on hand at any given time.

Operating Research and Test Reactors

Aerotest Operations Inc., San Ramon, CA
Armed Forces Radiobiological Research Institute, Bethesda, MD
Dow Chemical Company, Midland, MI
General Electric Company, Sunol, CA
Idaho State University, Pocatello, ID
Kansas State University, Manhattan, KS
Massachusetts Institute of Technology, Cambridge, MA
National Institute of Standards and Technology, Gaithersburg, MD
North Carolina State University, Raleigh, NC
Ohio State University, Columbus, OH
Oregon State University, Corvallis, OR
Penn State University, University Park, PA
Purdue University, West Lafayette, IN
Reed College, Portland, OR
Rensselaer Polytechnic Institute, Schenectady, NY
Rhode Island Atomic Energy Commission, Narrangansett, RI
Texas A&M University, College Station, TX (two reactors)
University of Arizona, Tucson, AZ
University of California-Davis, Sacramento, CA
University of California, Irvine, CA
University of Florida, Gainesville, FL
University of Maryland, College Park, MD
University of Massachusetts, Lowell, MA
University of Missouri, Columbia, MO
University of Missouri, Rolla, MO
University of New Mexico, Albuquerque, NM
University of Texas, Austin, TX
University of Utah, Salt Lake City, UT
University of Wisconsin, Madison, WI
U.S. Geological Survey, Denver, CO
Washington State University, Pullman, WA
Worcester Polytechnic Institute, Worcester, MA

Decommissioning Research and Test Reactors

These research and test reactors are authorized to decontaminate and dismantle their facility to prepare for final survey and license termination.

General Atomics, San Diego, CA (2 reactors)
National Aeronautics and Space Administration, Sandusky, OH (2 reactors)

University of Illinois, Urbana, IL
University of Washington, Seattle, WA
Viacom, Waltz Mill, PA

Permanently Shut Down Research and Test Reactors

These research and test reactors are permanently shut down and are only authorized to possess the nuclear material on-hand.

Cornell University Zero Power Reactor, Ithaca, NY (2 reactors)
General Electric Company, Sunol, CA (3 reactors)
Nuclear Ship Savannah, James River Reserve Fleet, VA
State University of New York, Buffalo, NY
University of Michigan, Ann Arbor, MI
U.S. Veterans Administration, Omaha, NE

Additional information is available on our website at:
http://www.nrc.gov/reactors/non-power.html .

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