A Vital Tool for Big Science

The birthplace of Oak Ridge National Laboratory, the X-10 Graphite Reactor was the world’s first continuously operated nuclear reactor. Built during the World War II Manhattan Project, the Graphite Reactor successfully produced plutonium (\(^{239}\text{Pu}\)) and enabled the demonstration of the chemical separation processes used to produce plutonium for the second atomic bomb.

After World War II, the reactor was the nation’s principal source of radioisotopes for academic, scientific, medical and industrial use, and supported research in many fields of physics, chemistry, biology and engineering.

GRAPHITE REACTOR FIRSTS

The ORNL Graphite Reactor was the first reactor to:

- Produce microgram quantities of plutonium used in developing a nuclear weapon
- Produce radioisotopes for science
- Produce electricity from nuclear energy and provide a test bed for the light water reactors used today
- Enable studies of the health hazards of reactor radiation
- Prove the feasibility of reprocessing nuclear fuel
- Produce a radioisotope, carbon-14, which was used to treat cancer
- Enable the discovery of a new element
- Enable studies of radiation damage to metals and the structure of matter using neutron scattering

Neutron Science, 1946: Future Nobel Laureate Clifford Shull and Ernest Wollan pioneer neutron scattering studies, demonstrating that neutrons can be used to probe the nature and structure of matter.

A Place in History

“From its secret birth to its reluctant retirement, the Graphite Reactor contributed immeasurably to the defense of this nation’s liberty, and to the betterment of man’s everyday life.”

Glenn Seaborg.
Chairman of the U.S. Atomic Energy Commission from 1961 to 1971
1939
THE ATOMIC AGE OPENS

Nobel Laureate Albert Einstein signs a letter to President Franklin D. Roosevelt asking the U.S. government to develop the fission bomb before Germany does.

Robert Oppenheimer and Albert Einstein

1940
AMERICAN DISCOVERIES

Multiple separation processes for enriching uranium are conceived. The electromagnetic separation process would later be used at Oak Ridge's Y-12 plant to supply uranium for the first atomic bomb.

Y-12 early construction

1941
THE UNITED STATES ENTERS WORLD WAR II

Plutonium is discovered by Glenn Seaborg at the University of California-Berkeley. Seaborg and his team develop a multistage chemical process to separate plutonium from uranium and concentrate and purify $^{239}$Pu.

On December 7, Japanese planes attack U.S. Navy ships at Pearl Harbor.

1942

The Manhattan Project is born. Col. Leslie Groves is charged with the military aspects of the project, and Robert Oppenheimer is tapped to lead the technical development. The goal of the project is production of uranium and plutonium and development of an atomic bomb.

USHERING IN THE ATOMIC AGE

In December the first sustained, controlled nuclear chain reaction is demonstrated at Chicago Pile 1 at the University of Chicago.

Enrico Fermi is chosen as manager of the Graphite Reactor project, and his team includes Eugene Wigner and Alvin Weinberg, future ORNL directors.

1943
GRAPHITE REACTOR IS BORN

The new laboratory is called Clinton Laboratories. From February to November, 150 buildings are erected, employing 3,000 construction workers and costing $12 million.

Graphite Reactor early construction

1944
THE RACE TO THE BOMB

The first gram quantities of purified plutonium are shipped from Clinton Laboratories to Site Y in Los Alamos, New Mexico.

At 5 a.m. on November 4, spontaneous nuclear chain reactions begin at the Graphite Reactor.
1945

The Bombs Drop, WWII Ends

August 6:
The United States drops a uranium-fueled atomic bomb on Hiroshima, Japan. The uranium came from the Y-12 plant in Oak Ridge.

August 9:
The United States drops a plutonium-fueled atomic bomb on Nagasaki, Japan. The plutonium came from the Hanford Engineer Works in Washington state.

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1946

Radioisotope Production and Neutron Science


1947

New Age of Discovery

The discovery of the element promethium is announced. It was isolated from by-products of uranium fission at the Graphite Reactor in 1945.

1948

Nuclear Power

Logan Emlet uses electricity produced by the Graphite Reactor to operate a small engine. This is the first demonstration that heat from a reactor can be used to produce electricity.

1963

End of an Era

The Graphite Reactor shuts down exactly 20 years after first going critical.

1966

A National Landmark

The Graphite Reactor is designated a Registered National Historic Landmark by the National Park Service.
What Is Nuclear Fission?

Nuclear fission occurs when the atomic nucleus of a heavy element, such as uranium or plutonium, absorbs a neutron and then splits apart into lighter atomic nuclei, releasing free neutrons and tremendous amounts of energy. The free neutrons can be absorbed by other heavy nuclei, triggering further fission events and creating a self-sustaining nuclear chain reaction.

The Graphite Reactor was fueled with natural uranium, with an isotopic composition of 99.3% $^{238}$U and 0.7% $^{235}$U. The reactor was designed to use the neutrons produced by $^{238}$U to convert $^{238}$U, which cannot support a chain reaction, to $^{239}$Pu, an isotope of plutonium.

Technology Innovations

The Graphite Reactor was designed with the controls, radiation shielding, and cooling systems needed for a production reactor. Its natural uranium fuel was created in the form of 1x4-inch slugs, encapsulated in gas-tight cylindrical aluminum jackets. These were inserted by hand into horizontal channels in the graphite moderator and pushed into position using long rods. Only 800 of the available 1,248 channels contained fuel slugs. The graphite moderator, a 24-foot cube made of stacked blocks, slowed the neutrons emitted by the fuel to a speed at which the uranium nuclei could readily absorb them.

With 24 to 54 slugs per channel, the reactor usually contained about 54 tons of fuel. Irradiated fuel slugs were pushed through the fuel channels to the back of the reactor, where they fell into a canal filled with water 20 feet deep. Here they were loaded into buckets using long poles and transported underwater to a cell in the adjacent chemical processing plant. The water and 7 feet of concrete surrounding the reactor prevented the escape of radiation.

During reactor operations, the nuclear chain reaction was controlled using a system of seven 8-foot-long control rods—three steel and cadmium rods that dropped vertically, and four steel and boron rods positioned horizontally—that could soak up neutrons. To start the reactor, the three vertical rods were raised from the core, and two horizontal rods were partially or completely withdrawn to adjust the power level.

The reactor had a maximum power of 4,000 kW and was cooled by air moved by huge fans. After passing through the reactor core, the cooling air was filtered, removing 99% of its radioactive particles, and exhausted through a 200-foot stack.