History of the GRAPHITE REACTOR at Oak Ridge National Laboratory

The Graphite Reactor, 1943-1963

GRAPHITE REACTOR FIRSTS

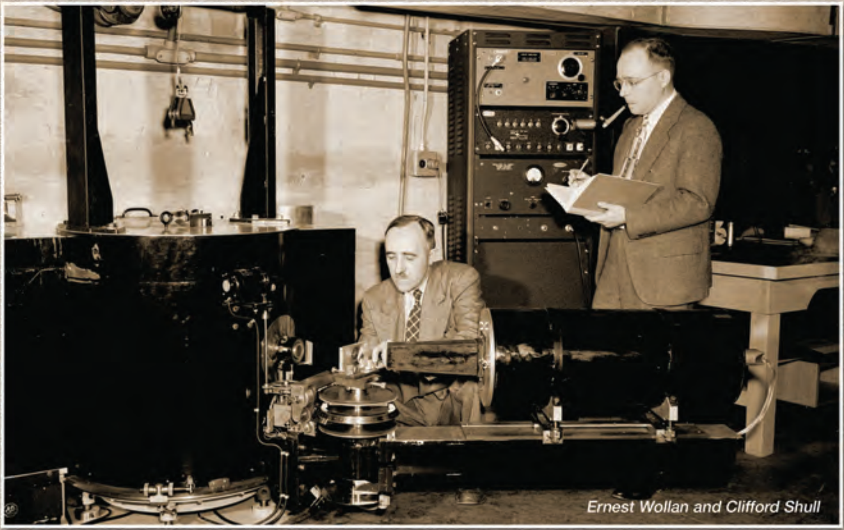
The ORNL Graphite Reactor was the first reactor to:

- 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

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}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.



Ernest Wollan and Clifford Shull

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

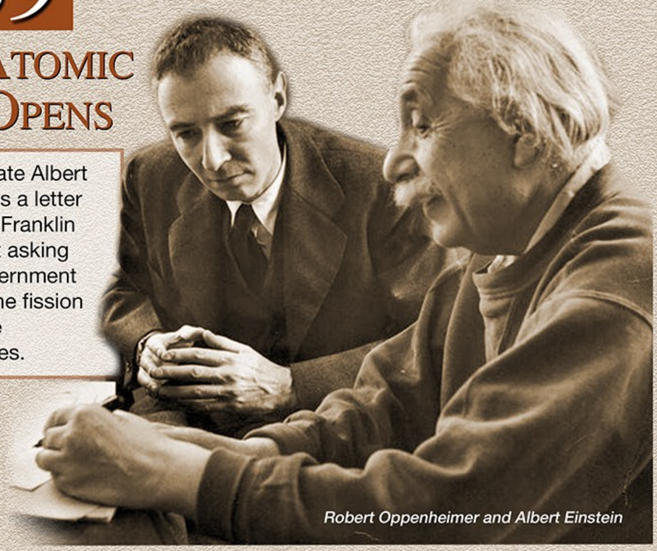
"From its secret birth to its reluctant retirement, the Graphite Reactor contributed immeasurably to the defense of this nation's liberty, and to the betterment of man's everyday life."

Glenn Seaborg,
Chairman of the U.S. Atomic Energy Commission from 1961 to 1971

Oak Ridge National Laboratory

U.S. Department of Energy

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

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

1944 The Race to the Bomb

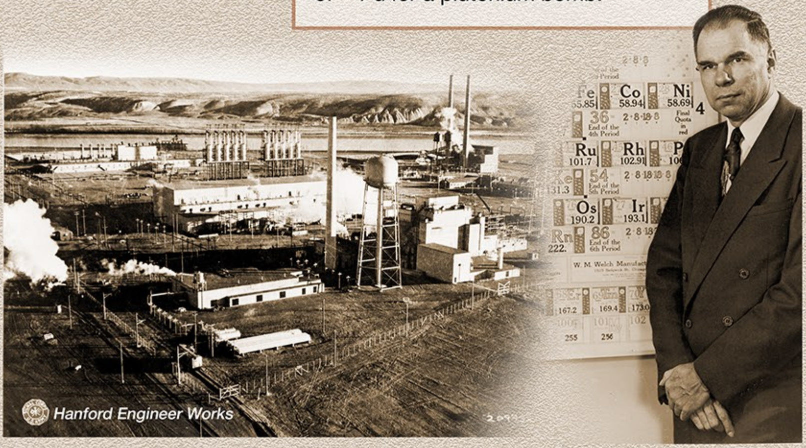
The first gram quantities of purified plutonium are shipped from Clinton Laboratories to Site Y in Los Alamos, New Mexico.

Site Y

X-10

1945

Plutonium production reactors at Hanford Engineer Works in Richland, Washington, produce usable quantities of ^{239}Pu for a plutonium bomb.



Hanford Engineer Works

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.

1946 Radioisotope Production and Neutron Science

The Graphite Reactor produces the first radioisotopes from a reactor, carbon-14. A new era of nuclear medicine begins.

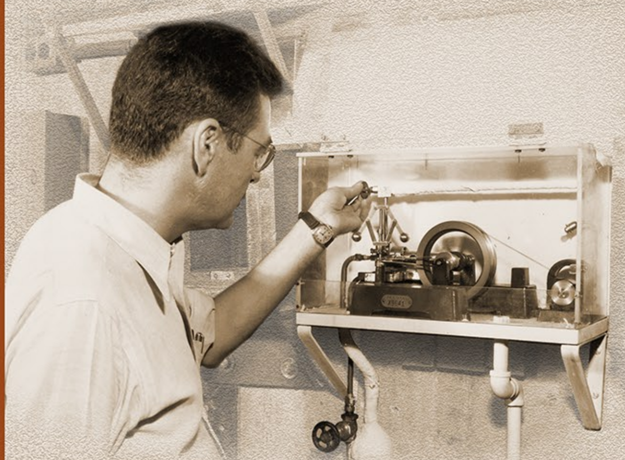
First medical radioisotopes

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.

X-10 REACTOR
OAK RIDGE NATIONAL LABORATORY
HAS BEEN DESIGNATED A
REGISTERED NATIONAL
HISTORIC LANDMARK
UNDER THE PROVISIONS OF THE
HISTORIC SITES ACT OF AUGUST 21, 1935
THIS SITE POSSESSES EXCEPTIONAL VALUE
IN COMMEMORATING OR ILLUSTRATING
THE HISTORY OF THE UNITED STATES
U. S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
1966

R.L. Doan, Alvin Weinberg, and Glenn Seaborg

History of the GRAPHITE REACTOR
at Oak Ridge National Laboratory

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 ^{235}U to convert ^{238}U, which cannot support a chain reaction, to ^{239}Pu, an isotope of plutonium.

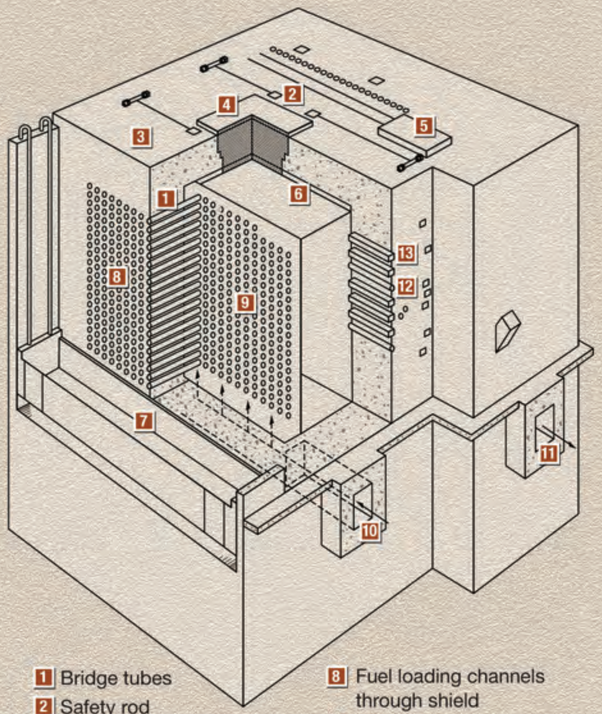
Technology Innovations

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 1×4-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.



1 Bridge tubes
2 Safety rod
3 7 ft. thick concrete shield
4 Graphite thermal column
5 Channel scanning device
6 Airflow baffle
7 Loading elevator
8 Fuel loading channels through shield
9 Uranium-graphite lattice
10 Air inlet
11 Air exhaust
12 Control rod location
13 Experimental hole