Graphite Reactor started up 70 years ago today

(As published in *The Oak Ridger's Historically Speaking* column on November 4, 2013)

The Manhattan Project National Historical Park will include (among other facilities) the National Historical Landmark Graphite Reactor at the Oak Ridge National Laboratory. It is among the most iconic symbols of the heritage of Oak Ridge. Today, November 4, 2013, at 5:00 AM is the 70th anniversary of that reactor going critical and sustaining a controlled nuclear reaction…the first in the world on an industrial scale.

This amazing and world changing technological achievement was the first major accomplishment of the Manhattan Project and it happened in Oak Ridge! This is an event worthy of substantial recognition and one that is cause for celebration. Oak Ridgers should show great pride in such a significant milestone.

The Graphite Reactor holds a number of firsts, among them the first production of electricity from a nuclear reactor, albeit a small flashlight bulb. It also was the first reactor to produce appreciable quantities of Plutonium. It was the first reactor to produce radioactive isotopes for medical research and treatment, agriculture, industrial applications and other purposes.

So, let's celebrate the 70th anniversary of the Graphite Reactor beginning the world's first sustained nuclear reaction in an industrial size reactor. Carolyn Krause brings us the following amazing story of the Graphite Reactor.

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For every problem there's a solution. For every solution there's a problem. That's what my electrical engineer brother has often said.

It was certainly true for the X-10 pile—the Graphite Reactor at Oak Ridge National Laboratory. It started operating 70 years ago today as a pilot plant that demonstrated that bomb-grade plutonium could be made in the world's first continuously operated nuclear reactor.

The early version of ORNL—Clinton Laboratories—also achieved the assigned goal of pioneering scaled-up chemical separation of plutonium from the uranium and other fission products.

Nobel Laureate Enrico Fermi at the University of Chicago was in charge of the design and construction of the X-10 reactor, which was built by DuPont. Fermi had led the team that achieved the world's first sustained chain reaction at the pile under the university's Stagg Field on Dec. 2, 1942.

Art Rupp had a lab near Stagg Field in 1942. After construction work on the X-10 pile started in February 1943, Rupp came to Clinton Laboratories in Oak Ridge. He was present at the startup of the Graphite Reactor.

"I recognized the magnitude of the event, and it was almost one of total amazement," Rupp told Steve Stow in an ORNL oral history interview. "I had a great deal of faith in the team of nuclear physicists under Fermi, who were doing all the physics work for the Graphite Reactor."

The physicists included Eugene Wigner, who became research director of ORNL in 1946-47 and won a Nobel Prize in physics in 1963, and Alvin Weinberg, director of ORNL from 1955 to 1973.

"I was assigned by Wigner to estimate the appropriate lattice configuration, the critical size, and the disposition of the control rods for the X-10 pile," Weinberg wrote in his book "The First Nuclear Era: The Life and Times of a Technological Fixer." Wigner, he added, was also a chemical engineer who argued strongly for cooling the X-10 pile with water.

Instead the aluminum-clad uranium cylinders (slugs) inserted in rows of evenly spaced long holes, or horizontal channels, in the large X-10 graphite block were cooled with flowing air. But, Wigner used water for cooling in his design of the three large reactors in Hanford, Wash.

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These reactors produced the plutonium used in the atomic bomb designed and built at Los Alamos, New Mexico, and dropped on Nagasaki, Japan, ending World War II. The Hanford reactors and plant were a scaled-up version of the Oak Ridge reactor and chemical separations facilities.

Fermi assigned Miles Leverett the task of setting up at Clinton Labs "what was ultimately the Technical Division with responsibility for the engineering design of the X-10 reactor," according to an article by Bill Yee, a former ORNL researcher.

Fermi and Leverett later received two patents for Leverett and T. V. Moore's design of the 1,248 horizontal channels in the Graphite Reactor, which enabled the production of macro amounts of plutonium-239 in a "continuous" manner.

"Slugs of natural uranium could be inserted into the graphite cube 24 feet on a side, exposed to a neutron field to produce plutonium-239, and pushed out of the reactor so that the slugs could be chemically treated to separate the plutonium," Yee wrote.

Up until that time, the only way to get to the exposed slugs was to dismantle Fermi's radioactive pile, which produced only batches of micro quantities of plutonium and would have exposed workers to hazardous radiation.

Leverett had worked in Glenn Seaborg's chemistry group at Chicago, which selected the bismuth phosphate chemical precipitation process to separate and recover plutonium-239. At Oak Ridge Leverett directed the engineering aspects of remotely extracting it from bulk quantities of irradiated natural uranium.

To protect workers from radiation at the X-10 reactor, engineers designed and built "hot cells" with five-foot-thick concrete walls and long pieces of equipment "for remotely handling highly radioactive materials [in the hot cells] and dealing with large quantities of radioactive waste on a scale never before attempted," Yee wrote.

On Nov. 3 at 8 a.m. workers in the first of two 12-hour shifts began inserting thousands of uranium slugs into the channels of the Graphite Reactor.

According to the ORNL Review, "The sequence involved loading a ton or two, withdrawing control rods to measure the increase in neutron flux, reinserting the rods into the pile, loading another batch of uranium, then stopping again to assess activity, each time attempting to estimate when the reactor would achieve a self-sustaining chain reaction."

After the day shift had loaded 10 tons, John Gillette, a DuPont engineer, came in at 8 p.m. and joined workers repeatedly racing to load a few slugs and take measurements.

Before the air-cooled Graphite Reactor went critical, a problem cropped up involving water.

"They tried to make the reactor go critical, but the reactor didn't start," Rupp said. "Then, it was realized that the reactor had retained some moisture. Water absorbs neutrons, so we ran the reactor with some heaters to get it all dried out."

The loading started up again but then was stopped when scientists in the plotting room recognized that one more batch of slugs would bring on criticality. According to the ORNL Review:

"Before dawn on Nov. 4, Louis Slotin [who died at age 36 from a plutonium accident in May 1946 in Los Alamos] drove to the Guest House [Alexander Inn] to awaken the two Nobel laureates, [Arthur] Compton and Fermi, known by the aliases Holley and Farmer in Oak Ridge. In the dark, they raced down Bethel Valley Road to witness the reactor going critical at 5:00 a.m. Scientists aware that the world's first powerful nuclear reactor had gone critical that morning were thrilled."

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Another problem surfaced in July 1944 after the Los Alamos lab had received several grams of plutonium from Oak Ridge. Emilio Segrè and colleagues confirmed that the plutonium contained not only plutonium-239 but also high levels of plutonium-240, which emits neutrons spontaneously.

This observation meant that the plutonium could detonate too soon, ruling out the planned gun-type nuclear weapon. But Robert Oppenheimer's Los Alamos lab solved the problem by designing and building an implosion-type nuclear weapon.

For every problem, there is a solution, and for every solution, there is a problem.
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Thank you Carolyn. The history surrounding the Graphite Reactor is a key element in the heritage of Oak Ridge. Taking the time to recognize the 70th anniversary of the startup of that first industrial sized reactor will encourage all of us to think toward the time when we will have an element of the Manhattan Project National Historical Park right here in Oak Ridge. A mainstay of that park will be the historic Graphite Reactor.

A view of the loading face and visitor seating area of the Graphite Reactor (photo provided by the Oak Ridge National Laboratory)

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A wide view of what the visitor sees upon first entering the reactor museum (photo provided by the Oak Ridge National Laboratory)

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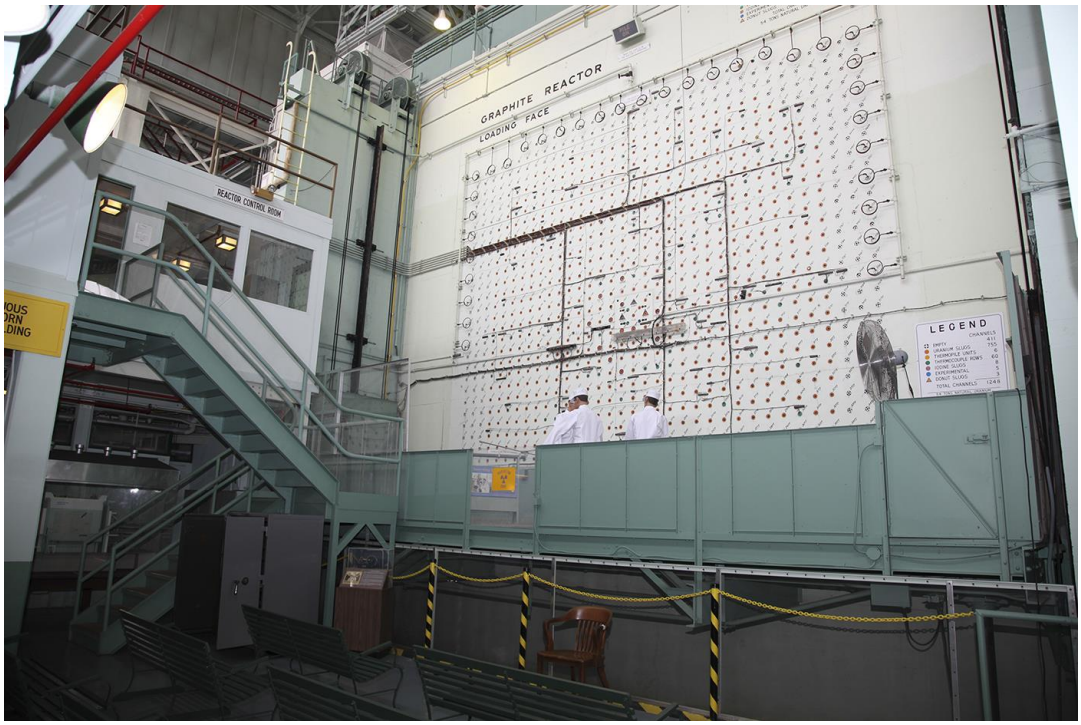

The loading face and control room – note the small display at the bottom left is the electrical generator that produced the world's first electricity from a nuclear reactor (photo provided by the Oak Ridge National Laboratory)

An exterior view from the north looking south (photo provided by the Oak Ridge National Laboratory)

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Exterior view showing the main entrance (photo provided by the Oak Ridge National Laboratory)

View from the south looking northwest (photo provided by the Oak Ridge National Laboratory)