The Oak Ridge Graphite Reactor – a History by Don Miller

(As published in The Oak Ridger's Historically Speaking column on March 28, 2016)

On February 18, 2016, a group of volunteers from the Great Smoky Mountain National Park visited Oak Ridge to experience the newest National Park unit, the Manhattan Project National Historical Park, or at least part of it. Don Miller arranged for several of his fellow volunteers there to make the trip.

One of the historic sites he arranged for them to visit was The Graphite Reactor at the Oak Ridge National Laboratory. He told them they would be visiting a World War II structure built between February and November 1943 designed to use natural uranium in a controlled nuclear chain reaction.

The rest of this Historically Speaking column is the information Don provided his fellow volunteers to help prepare them to better enjoy the visit to one of Oak Ridge's most historic sites.

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In May 1941, Niels Bohr and John Wheeler, University of California, had theorized that heavy isotopes with odd atomic numbers were fissile. If so, then plutonium-239 was likely to be an option for constructing a bomb as was already planned for uranium.

Emilio Segrè and Glenn Seaborg at the University of California produced 28 μg of plutonium in the 60-inch cyclotron there in May 1941, and found that it had 1.7 times the thermal neutron capture cross section of uranium-235. In other words, plutonium would be capable of developing a stronger blast if it could be designed into a bomb!

These two events were to combine in the United States' urgent war weapons planning and resulted in this reactor being built in the Clinton Engineer Works, later Oak Ridge.

The University of Chicago's Pile-1 reactor, constructed under the west viewing stands of the original Stagg Field, went critical on December 2, 1942. This reactor generated up to 200 Watts of heat enough to power a light globe.

Moving directly to a megawatt production plant looked like a big step, given that many industrial processes do not easily scale from the laboratory to production size. An intermediate step was considered prudent. It was hoped that problems would be found in time to correct them in the production plants. The semi-works (Graphite Pile) at Oak Ridge would also be used for training, and for developing procedures.

As plans progressed, DuPont completed the Graphite Reactor design and Some 700 tons of graphite blocks were purchased from National Carbon. The construction crews began stacking it in September 1943. Meanwhile Alcoa Aluminum was contracted to encase the uranium fuel slugs, which started production on June 1943.

In September 1942, Compton asked a physicist, Martin D. Whitaker, to form a skeleton operating staff for X-10. Whitaker became the inaugural director of the Clinton Laboratories. The first permanent operating staff arrived in Oak Ridge from the Metallurgical Laboratory in Chicago in April 1944, by which time DuPont began transferring its technicians to the site. They were augmented by one hundred technicians in uniform from the Army's Special Engineer Detachment.

By March 1944, there were some 1,500 people working at X-10.

The first batch of fuel slugs was received from Alcoa on December 20, 1943, allowing the first plutonium to be produced in early 1944. The fuel slugs used pure metallic natural uranium, in air-tight aluminum cans 4.1 inches long and 1 inch in diameter.

Each channel was loaded with between 24 and 54 fuel slugs. It went critical with 30 tons of fuel, but in its later life was operated with as much as 54 tons.

To load a channel, the radiation-absorbing shield plug was removed, and the slugs inserted manually in the front end with long rods. To unload them, they were pushed all the way through to the far end, where they fell onto a neoprene slab and fell down a chute into a 20-foot deep pool of water that acted as a radiation shield.

Following weeks of underwater storage to allow for decay in radioactivity, the slugs were delivered to the nearby chemical separation building.

It was, at one time, the oldest continuously operating nuclear reactor in the world. It has facilities for research in industry, medicine, agriculture and biology. At one time, there were 2,700 users of the produced radioisotopes through the United States and 57 foreign countries.

The external dimensions of the reactor structure is 38 feet by 47 feet, with a height of 35 feet. For operation, four technical and fifteen non-technical staff were needed to operate the reactor. When the amount of uranium required for operation is in the reactor, a chain reaction is spontaneous.

Thus, the reactor must have enough neutron absorbers in its safety and control system to engage neutrons much faster than they can be produced by the reaction. The safety system consists of three rods of cadmium and two of steel. The steel rods served as operating control devices driven hydraulically and monitored by the reactor operator.

The moderator for the reactor was graphite. The coolant was atmospheric air. The neutron energy was thermal. The power generated was 3.5 Megawatts.

The X-10 Graphite Reactor was shut down on November 4, 1963, after twenty years of use. It was added to the National Register of Historic Places on December 21, 1965, and was designated a National Historic Landmark on October 15, 1966.

It never had an operational incident (malfunction).

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Thanks to Don Miller for compiling this data on the historic Graphite Reactor. Don is a former staff member of the Oak Ridge National Laboratory's Instruments & Controls Division.

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Don Miller when he worked at the Graphite Reactor

A recent photo of Don Miller

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The side of the Graphite Reactor where the isotopes were inserted and removed to produce radionuclides for nuclear medicine and other research purposes

The radionuclides were placed in lead containers for shipment to hospitals and research facilities