

The in-and-out history of plutonium in Oak Ridge

(As published in *The Oak Ridger's Historically Speaking* column on January 18, 2016)

Carolyn Krause concludes her series on Plutonium and Oak Ridge with this installment that focuses on Louis Slotin. She also mentions the recent history of the Oak Ridge National Laboratory's latest production of Plutonium 238 for use in space exploration.

So, let's explore our Oak Ridge Plutonium history a bit further with Carolyn's help.

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Oak Ridge has largely been a source of highly enriched and low-enriched uranium throughout its 72-year history, but plutonium has also played a role in the Oak Ridge story.

Think about Enrico Fermi, the Graphite Reactor, Eugene Wigner, the Clinch River Breeder Reactor Project and Louis Slotin (who endangered himself in Oak Ridge and Los Alamos).

Just last month, Oak Ridge National Laboratory announced it had produced 50 grams of plutonium-238 -- roughly the mass of a golf ball -- as a power source for NASA's deep-space missions. This production success at ORNL's High Flux Isotope Reactor is deemed an important milestone in re-establishing a U.S. stockpile of Pu-238 for space exploration.

In mid-1942 Oak Ridge was initially selected as a site for large-scale production of plutonium-239, as well as uranium-235, to fuel the atomic bombs later developed at Los Alamos, N.M. The reason: the large amount of power that the Tennessee Valley Authority could supply. But the proximity of Knoxville altered the federal government's decision.

According to Henry D. Smyth's "Atomic Energy for Military Purposes," "Reconsideration at the end of 1942 led General Groves to the conclusion that this site was not sufficiently isolated for a large-scale plutonium production plant. At that time, it was conceivable that conditions might arise under which a large pile might spread radioactive material over a large enough area to endanger neighboring centers of population."

So, to meet the two requirements of isolation and sufficient power, the decision was made to build large plutonium-producing reactors at a new site "on the Columbia River in the central part of the state of Washington near the Grand Coulee [Dam] power line," Smyth wrote, "This site was known as the Hanford Engineer Works."

What Oak Ridge did get was the air-cooled, graphite-moderated Clinton Pile (Graphite Reactor), a pilot plant at which Clinton Laboratories' researchers demonstrated that plutonium-239 could be produced in and separated from the uranium-238 slugs. Nobel Laureate Enrico Fermi, who was based at the University of Chicago, led the reactor project.

In late 1943 the Graphite Reactor began operating. As the double issue of the ORNL Review in 1993 reported, "Before dawn on November 4, Louis Slotin drove to the Guest House to awaken the two Nobel laureates, [Arthur] Compton and [Enrico] 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."

Small amounts of the total of 326 grams of plutonium produced at the Graphite Reactor were shipped by several train trips to Los Alamos. There the radioactive isotope was used experimentally, leading to the design of an implosion-type, plutonium-fueled bomb.

The plutonium production and reprocessing procedures at Oak Ridge were scaled up at Hanford. The water-cooled, graphite-moderated reactors there were designed by future Nobel laureate Eugene Wigner, a chemical engineer and physicist who was research director in 1946-47 at what became ORNL.

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On Aug. 9, 1945, three days after the atomic bomb using uranium fuel from Oak Ridge was detonated over Hiroshima, Japan, an implosion-type, plutonium-fueled bomb was dropped on Nagasaki, Japan, ending World War II.

One of the most dramatic figures in the national plutonium research story was Louis Slotin, Compton and Fermi's Oak Ridge chauffeur. According to Wikipedia, Slotin worked on the production of plutonium under Wigner at the University of Chicago and at ORNL before moving to the Los Alamos laboratory in December 1944 to work in the bomb physics group.

While at Oak Ridge, Slotin shocked people with his recklessness, especially Karl Morgan, director of ORNL's Health Physics Division. Slotin wanted the Graphite Reactor shut down immediately so he could repair a malfunctioning instrument associated with his experiment six feet under water. The Canadian scientist was told to wait an extra day when the reactor would be shut down for a scheduled refueling and the water tank would be drained.

In his publication "The Angry Genie: One Man's Walk through the Nuclear Age," Morgan wrote: "But during the night Slotin stripped down to his shorts, dove to the bottom of the water tank, and repaired his equipment. He did not wear his film badge (dosimeter), so we could only estimate his radiation dose to be at least 100 roentgens"—a hazardous but survivable amount.

On July 16, 1945, Slotin assembled the core for Trinity, the first detonated atomic device; he became known as the "chief armorer of the United States" for his expertise in assembling nuclear weapons from plutonium.

On May 21, 1946, at Los Alamos, seven colleagues watched Slotin try to determine critical mass (the least amount of fissile material needed to maintain a nuclear chain reaction) by gradually bringing together two beryllium-coated halves of a sphere that held plutonium at the core. Slotin used a screwdriver to prevent the halves from touching and recorded the increasing rate of fission. The screwdriver slipped and a blue glow flashed, exposing Slotin to a lethal dose of radiation. He knocked the spheres apart, stopping the chain reaction, and told his colleagues to run away. Slotin suffered horrible effects and died nine days later.

None of the eight were wearing film badges. Although improper procedures (e.g., the screwdriver) were used and the lives of several of his colleagues might have been shortened by the radiation exposure, Slotin was hailed as a hero by some for saving his colleagues' lives. Some admirers later made movies about him.

Oak Ridge was the planned site for the Clinch River Breeder Reactor Project, a joint effort of DOE (including its predecessors) and the U.S. electric industry. First funded in 1972, the prototype of a sodium-cooled, fast-neutron reactor designed to "breed" plutonium-239 nuclear fuel from uranium-238 was supposed to be built on Tennessee Valley Authority land on the north bank of the Clinch River.

But Congress was troubled by the project and technology costs, and President Jimmy Carter was concerned about nuclear weapons proliferation – the production of plutonium that could be diverted by outlaw nations and terrorists for the manufacture of atomic weapons.

In 1979 he restated his opposition to continuing the Liquid Metal Fast Breeder Reactor's funding, saying, "The Clinch River breeder reactor is a technological dinosaur. It's a waste of more than one-and-a-half billion dollars of taxpayers' money. It's an assault on our attempts to control the spread of dangerous nuclear materials. It marches our nuclear policy in exactly the wrong direction. This is no time to change America into a plutonium society."

President Ronald Reagan revived the CRBRP but Congress ended its funding in 1983.

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Now, Oak Ridge is back in the production of small amounts of plutonium, this time for space missions. Pu-238, which differs from the Pu-239 isotope used in nuclear weapons, is needed to fuel future radioisotope thermoelectric generators, or RTGs. As it decays, radioactive Pu-238 produces heat, which the RTG turns into electricity for spacecraft tasks.

The previous U.S. source of Pu-238, a reactor at DOE's Savannah River Plant in South Carolina, was shut down in the late 1980s. The current U.S. inventory of Pu-238 is only about 35 kilograms, including what is left from the Savannah River production and recent procurements from Russia.

Once the ORNL capabilities of producing Pu-238 (by irradiating neptunium-237 in HFIR), separating the plutonium from the targets, and purifying Pu-238 in shielded hot cells are scaled up and automated, ORNL will have the only U.S. infrastructure for providing a steady and growing supply of plutonium-238—from 300 grams to as much as 1.5 kilograms each year—for future space missions.

According to NASA, the next mission with plans for using an RTG is the Mars 2020 Rover, which is tentatively scheduled for launch in July 2020. NASA also stated, "The mission seeks signs of life on Mars and will test technology for human exploration and gather samples of rocks and soil that could be returned to Earth."

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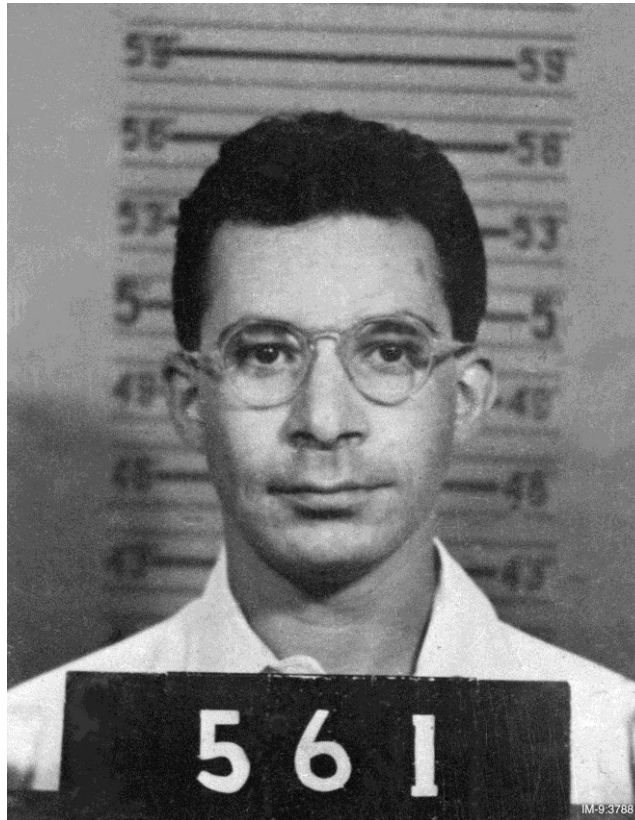
Thank you Carolyn for a really well done article explaining some of the various aspects of the history of Plutonium and Oak Ridge. The Louis Slotin story is one of a sad reality that reinforces the need to take necessary precautions when working with potentially dangerous materials such as Plutonium.

While such accidents are never desirable and hopefully can be avoided, the lessons learned from such early attempts to understand unknowns are all too often fraught with danger. All the more reason to proceed with due caution and to follow established rules and regulations for handling materials with potential to be hazardous.

Ultimately Conduct of Operations practices are required to assure safe handling of hazardous materials. The nuclear industry realizes this as much if not more than anyone else.

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Louis Slotin, an expert on plutonium and bomb assembly, worked at both at Oak Ridge and Los Alamos during World War II and died from a radiation accident while conducting an experiment at Los Alamos. His death led to tighter restrictions to prevent such accidents

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Slotin accident mock-up.jpg: In this “tickling the tail of the dragon” experiment, Louis Slotin moved the top of the plutonium-containing half-sphere with his thumb in the hole and kept the two half-spheres separated with a screwdriver (a violation of the experimental protocol)