The Production and Distribution of Radioisotopes

Oak Ridge National Laboratory

March 6, 2008

A National Historic Chemical Landmark

AMERICAN CHEMICAL SOCIETY

SCIENCE THAT MATTERS

> "If at some time a heavenly angel should ask what the Laboratory in the hills of East Tennessee did to enlarge man's life and make it better, I daresay the production of radioisotopes for scientific research and medical treatment will surely rate as a candidate for first place."
>
> Alvin Weinberg, Director, Oak Ridge National Laboratory, 1955-1973.

radioisotopes

1945

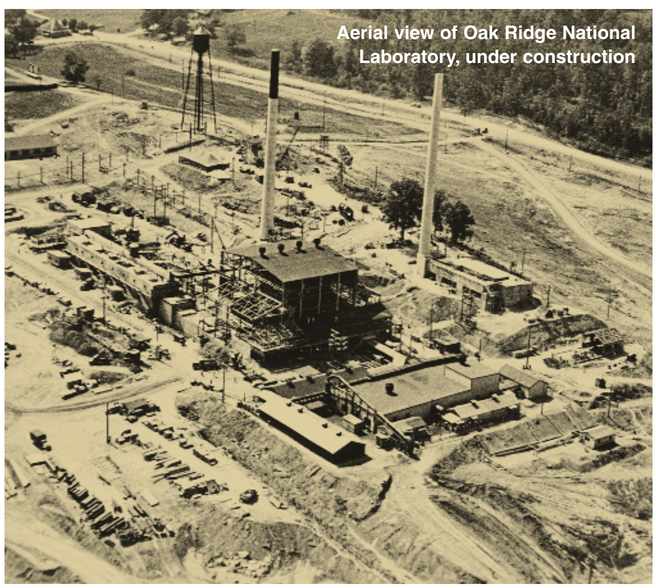
August 1945: The United States drops two atomic bombs on Japan, the culmination of the wartime Manhattan Project. Faced with the prospect of further unprecedented and unimaginable destruction, Imperial Japan surrenders.

In eastern Tennessee, the staff at Clinton Laboratories (now Oak Ridge National Laboratory), proud of its contribution to the war effort and, like all Americans, relieved the war is over, understandably faces the future with anxiety. Would the federal government fund peacetime atomic research? Would it, in other words, invest in the peaceful uses of nuclear energy at levels remotely approaching the investment in weapons production? Would the scientists, caught up in the fervor of the war years, stay in the rural hills of eastern Tennessee instead of returning to universities and research laboratories? Were there even peacetime uses for their laboratory? As Alvin Weinberg, later the facility's director for many years, said: "During those days immediately after the war, everything seemed ambiguous."

One of those who thought the laboratory had a future was Eugene Wigner, one of the legendary refugee scientists from Fascist Europe who provided the theoretical and practical knowledge that fueled the Manhattan project. Wigner became director of research and development at Clinton Laboratories in 1946, but as early as 1944 he had drawn up plans for a postwar facility with a staff of about 3500 devoted to nuclear research.

Origins

The story behind the decision of President Franklin Roosevelt to develop the atomic bomb is well known. The decision grew out of fear on the part of a number of scientists that Nazi Germany might build the bomb first. To prevent that, Roosevelt assigned a unit of the U.S. Army Corps of Engineers, headquartered near New York's City Hall in Manhattan, to coordinate nuclear weapons research. General Leslie Groves, named commander of the project in 1942, worried the project's original name, "Laboratory for the Development of Substitute Materials," might draw undue attention; accordingly, he dubbed it the "Manhattan Engineer District," soon shortened to the "Manhattan Project." Research and production took place at a number of sites, with Clinton Laboratories commissioned to produce and isolate gram quantities of plutonium.



Aerial view of Oak Ridge National Laboratory, under construction

The history of Oak Ridge National Laboratory (ORNL) is linked with another project: The Tennessee Valley Authority. ORNL and TVA share a common geography – East Tennessee – and a common political heritage as large, government-sponsored projects of the Roosevelt administration. At first glance, East Tennessee did not seem a propitious site for a war-related facility: the region had very few scientists and no sophisticated laboratory equipment. But it did have cheap and abundant electricity, thanks to TVA, and its isolation proved a plus because the top-secret facility would be located far from prying eyes. Accordingly, on February 1, 1943, construction began on the world's first operational nuclear reactor, known as the "Clinton Pile," or the Graphite Reactor. It took only nine months to build the pile, which became critical on November 4 (the first experimental nuclear reactor, which produced the first sustained nuclear reaction, had been built the year before in Chicago by Enrico Fermi and his colleagues).

The goal of the Clinton facility, code-named X-10, was to bombard uranium-238 with neutrons to produce plutonium for developing a nuclear weapon. As such, X-10 was a demonstration plant for the production of plutonium from uranium. Eventually, other facilities built on the pilot work done at Clinton to produce the plutonium used in the atomic bomb dropped on Nagasaki, Japan.

Oak Ridge National Laboratory and Radioisotopes

The production and distribution of radioisotopes became part of the answer to the question of what would happen after the end of World War II to Clinton Laboratories, which fell under the purview of the Atomic Energy Commission (AEC), created in 1946 to oversee the transfer of atomic energy from military to civilian control. In 1947, the AEC changed the name to Clinton National Laboratory (in 1948 the named changed again, to Oak Ridge National Laboratory). More importantly, the AEC decided to utilize the existing Graphite Reactor at

Radioisotopes

An isotope is a form of a chemical element. All isotopes of an element share the same position in the periodic table [isotope from the Greek isos (same) and topos (place)] and they have the same atomic number (same number of protons in the nucleus). What differentiates isotopes is the number of neutrons in the nuclei, giving them different atomic masses. A radioisotope is an atom with an unstable nucleus that decays to a stable form with the emission of radiation. Most radioisotopes (radioactive isotopes) are artificially produced, though some unstable natural isotopes, notably uranium-235, exist in nature.

The most common method of producing radioisotopes is by neutron activation in a nuclear reactor; this involves the capture of a neutron by a nucleus which leads to an excess of neutrons (a neutron-rich atom). Other radioisotopes are manufactured in a cyclotron in which protons are introduced into the nucleus; this results in a deficiency of neutrons (a proton-rich nucleus). Nuclear reactor-produced radioisotopes are formed either by the fission of uranium-235, which maintains the chain reaction, or by neutron absorption by non-fissionable nuclei placed inside the reactor.

Radioisotopes and Their Uses

Americium-241	Smoke detectors
Barium-133	Metal thickness gauge applications
Bismuth-213	Cancer therapy
Carbon-14	Tracer for following chemical reactions
	Tracer for nutrients and pharmaceuticals
Cesium-131	Prostate cancer therapy
Cesium-137	Determining soil erosion in reservoirs
	Cargo screening at ports
Cobalt-60	Testing welds and materials
	Food irradiation to kill microorganisms
	Cancer therapy
Copper-64	Measuring heavy metal contamination
Fluorine-18	PET imaging
Gallium-67	Tumor imaging
Iodine-131	Thyroid cancer therapy
Iridium-192	Various cancer therapies
Nickel-63	Detection of explosives, pollutants, and drugs
Phosphorus-32	DNA analysis
Plutonium-238	Power source for spacecrafts
Technetium-99	Diagnostic imaging; medical tracing

Note: This is only a partial list.

Clinton and to take advantage of the facility's scientific knowledge by maintaining it as a center for basic and applied chemical research and for isotope research and production.

On June 14, 1946, before the AEC became operational, the laboratory published in *Science* magazine a catalogue of reactor-produced isotopes that Clinton could prepare and distribute for scientific and medical uses. The list included almost twenty fission-produced isotopes and about sixty non-fission products available to qualified researchers. On August 2 Eugene Wigner, standing in front of the Graphite Reactor, presented a small container of carbon-14 to the director of the Barnard Free Skin and Cancer Hospital of St. Louis. That presentation marked the beginning of the peacetime uses of atomic energy.

In the first year of production, Clinton made more than a thousand shipments of radioisotopes, mostly of iodine-131, phosphorus-32, and carbon-14; by 1950, the number of shipments neared 20,000. After the closing of the Graphite Reactor in 1963, production shifted to the Oak Ridge Research Reactor, which produced radioisotopes until 1987. Today, most radioisotopes are made outside the United States, but ORNL continues to produce specialty isotopes at its High Flux Isotope Reactor.

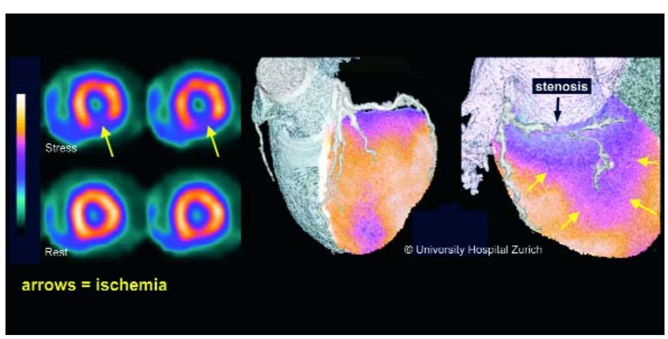
Uses of Radioisotopes

Nuclear medicine began in the 1950s with physicians using iodine-131 to diagnose and treat thyroid diseases, an extremely successful therapy. Today, more than ten million therapeutic procedures using radioisotopes ("nuclear-medicine" procedures) are performed on patients in the United States every year and more than 100 million nuclear-medicine diagnostic tests are conducted on Americans annually. For most people, it is nuclear medicine that demonstrates the usefulness of radioisotopes. As many as one hundred radioisotopes are used in diagnosis or therapy.

Over the years, radioisotopes of carbon, cesium, cobalt, and many others [see chart] have been used in cancer therapy. Other isotopes, notably technetium-99, have a multitude of uses for diagnostic imaging. Diagnostic techniques employ short-lived radioactive tracers which emit gamma rays; images are recorded at intervals as the isotopes move through the body.

Radioisotopes are used in agricultural research to study the absorption of nutrients by plants. Plant hybridizers use radiation to induce mutations in developing new varieties. Many industrial applications of radioisotopes are related to process control which utilizes radioactive tracers to measure product flow and efficiency.

The rich variety of radioisotopes growing out of the Manhattan Project was the result of scientific inquiry, research, and experimentation that devised peacetime uses for nuclear energy. In turn, radioisotopes led to major scientific advances. For example, scientists employed carbon-14 to understand the mechanism of photosynthesis and to study steroid biosynthesis. And there are undoubtedly more advances to come as scientists harness more radioisotopes.



A fusion of single photon emission computed tomography (SPECT), which uses noninvasive imaging systems and pharmaceutical tracers to show the function and metabolism of cells in the body, with computed tomography (CT), which uses X-rays to produce detailed anatomical pictures.

Image credit: Oliver Gaemperli and Philipp A Kaufmann, University Hospital Zurich, Switzerland.

National Historic Chemical Landmark

The American Chemical Society designated the production and distribution of radioactive isotopes for peacetime uses at Oak Ridge National Laboratory as a National Historic Chemical Landmark in a ceremony in Oak Ridge, Tennessee, on March 6, 2008. The plaque commemorating the discovery reads:

On August 2, 1946, Clinton Laboratories, later renamed Oak Ridge National Laboratory (ORNL), delivered a small quantity of carbon-14 to a cancer hospital in St. Louis, marking the conversion of the Manhattan Project from wartime to peacetime pursuits. Over the ensuing decades, ORNL provided thousands of shipments of radioisotopes – radioactive forms of elements – to research laboratories and medical centers. Originally produced at the Graphite Reactor, the first operational nuclear reactor, these isotopes have numerous significant scientific and medical applications, both diagnostic and therapeutic, as well as many industrial and agricultural uses. For example, carbon-14 is used to follow chemical reactions; iodine-131 for thyroid cancer therapy; and phosphorus-32 to treat leukemia and ovarian cancer.

About the National Historic Chemical Landmarks Program

The American Chemical Society, the world's largest scientific society with more than 160,000 members, has designated landmarks in the history of chemistry since 1993. The process begins at the local level. Members identify milestones in their cities or regions, document their importance, and nominate them for landmark designation. An international committee of chemists, chemical engineers, museum curators, and historians evaluates each nomination. For more information, please call the Office of Communications at 202-872-6274 or 800-227-5558, e-mail us at nhclp@acs.org, or visit our web site: www.acs.org/landmarks.

A nonprofit organization, the American Chemical Society publishes scientific journals and databases, convenes major research conferences, and provides educational, science policy, and career programs in chemistry. Its main offices are in Washington, DC, and Columbus, Ohio.

Acknowledgments:

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Written by Judah Ginsberg

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