A safety review of the Oak Ridge Critical Experiments Facility

First, let me correct a mistaken in my last article. Harry K. Daghlian Jr., was the first person to die in a peacetime nuclear criticality accident. On August 21, 1945, he accidently dropped a neutron reflector brick on a plutonium core causing a burst of radiation resulting in his death 25 days later.

Louis Slotin, on May 21, 1946, was using the exact same plutonium core and another type of neutron reflector when a screwdriver he was using to hold the two pieces apart slipped allowing the reflector to fall on the core and causing a burst of radiation. He died nine days later, evidently in the same hospital bed where Daghlian had died some eight months earlier.

The core was referred to as the "Demon Core" because of these two deaths. After these two accidents the core was used in the ABLE atomic explosion of the Operations Crossroads nuclear weapons test on July 1, 1946, at the Bikini Atoll in the Pacific Ocean.

In December of 1962, a safety document was produced regarding the operations of Building 9213. Some of the historical information there is helpful to better understand this unique facility and its operations from 1950 until 1973. I recently learned of a later operation in the 1980's – more on that one in an upcoming installment of the amazing history of Building 9213.

The building itself is described, in 1962, as being, "located at a remote site in the southwest portion of the Y-12 Area. It is situated in a pocket in the terrain formed by surrounding hills several hundred feet higher than the building itself." The building is surrounded by a fence. "Gates in the fence, except for the one at the entrance to the facility, are kept locked."

The document describes three "assembly areas or test cells that extend the full height of the building" and designates those assembly areas as the South, East and West Assembly Areas and states they surround the original structure where the vault remains intact to this day. The East and West Assembly Areas were added in 1950. The South Assembly Area was added in 1957 and is separated from the east cell by a five-foot thick concrete wall.

Building 9213 is a two-story building, but these large assembly rooms fill the entire height of approximately 35 feet. Each cell is described as having a "control room" that is separated from the cell by a five-foot thick concrete wall. Visual communication is said to be enabled "by water-filled windows," and "verbal communication by an intercom."

The roof has been reinforced with a one-foot concrete slab to minimize radiation exposure through the air. The safety document indicated that this feature was not an original design of the building but was added later when the potential effects of the experiments to be conducted there were analyzed for safety of the operators.

The introduction to the study contains some broad generalizations about the facility. The purpose for constructing Building 9213 is stated as "…to meet the needs of various programs in Oak Ridge, and inevitably outside Oak Ridge, for data from low-energy, potentially chain-reacting assemblies. The programs have required the accumulation of basic reactor physics data, the determination of the critical dimensions of material assemblies, and the study of potential nuclear reactor designs."

The safety study further states, "Only in exceptional instances is it necessary to operate critical experiments at nuclear powers sufficiently high to present radiation hazards to the individuals performing the experiments…." To avoid any possible radiation exposure, Building 9213 was designed with laboratories equipped for remote performance of these experiments.

The Critical Experiments Facility was designed to allow critical experiments to be performed in a very wide variety. Thus the equipment selected for the facility had to be adaptable to many configurations. The reason for many of these critical experiments done in this facility over the years was to evaluate those

factors upon which reactor safety was to subsequently be designed. Of course, the more general nature of Criticality Safety was a primary result for Y-12.

Because of the relatively small inventory of fissile material used in these experiments, the safety features were well beyond the minimum necessary for protection of personnel. However, the variety of experiments required close scrutiny to assure limits were never exceeded.

Experiments described in the safety document include "…those performed on liquid solutions of uranyl nitrate…inaugurated in 1950," where "…the critical parameters…have been measured." This was done as Y-12 was beginning to work with liquid solutions in larger quantities, and the criticality information was vital to successful and safe operations.

Also included in the document, "For the Aircraft Nuclear Propulsion Project, for example, a long series of experiments was performed with heterogeneous combinations of uranium." Other materials including Teflon, and Plexiglas are mentioned as well. Of course, the attempt here was to determine just what shielding would be required to fly people safely in an airplane powered by a small nuclear reactor. As the saying goes, this project, although lasting several years, never did "get off the ground."

Experiments were also conducted with "…solid uranium-235 billets to determine the safe storage criteria." Other experiments for the Health Physics Research Reactor and the Army Package Power Reactor were also included.

The document states "The unique geometry of the Tower Shielding Reactor II was first investigated…" here in the Critical Experiment Facility. Also mentioned is that "The High Flux Isotope Reactor Critical Experiment No. 1 was an exploratory series of experiments with four liquid regions…."

The Criticality Testing Unit for solids is described in the report as being "two tables: a fixed table which is manually adjustable in elevation, and a vertically movable platform powered, through a magnetic coupling, by a pneumatic-hydraulic system to bring the parts of an assembly together." The fail-safe was the magnetic coupling that, when limits were exceeded, removed the current to the magnet releasing the movable table to fall away from the other table by the force of gravity.

The Criticality Testing System for solutions was different in that valves and long cylinders served as tanks and the "dump" mechanism provided for quick drain of the system into a safe geometry vessel. The instrumentation to monitor these experiments is described in some detail as are the safety systems allowing for safe operations.

Although safeguards were used and care exercised, there were still incidents where experiments did not go as expected or where equipment failed to function as expected. Contamination of the facility and exposure (all within allowable limits) occurred. According to the safety report, the "most severe accident in the history of the facility occurred in the spring of 1951…."

A polonium neutron source was fabricated in such a manner to allow the capsule to open unexpectedly and spilled the material inside one of the test cells. The many small items in the test cell were disposed of and the cell decontaminated in what was described in the report as "…a long and laborious process."

Many of the improvements in handling uranium safely and avoiding criticality accidents were the result of the work done by the nuclear pioneers at the Building 9213 Critical Experiments Facility. A small staff of about ten individuals, highly skilled and well trained in their field, took on the tremendous challenge of creating procedures to allow others, less well versed in the science, to work safely with fissile materials.