Executive Summary

Building 3042, The Oak Ridge National Laboratory Research Reactor, Oak Ridge, Tennessee

In December 1944, its initial wartime mission completed, the X-10 Graphite Reactor complex began to transition from plutonium production to experimental research in the emerging field of nuclear science and technology. By 1950, the activities at the Oak Ridge National Laboratory (ORNL) that required neutrons—isotope production; basic and applied physics, chemistry, and biology; and reactor development—had increased to the point that the X-10 Graphite Reactor could no longer meet demand. In addition, ORNL researchers needed a more convenient and versatile reactor than the high-flux Materials Testing Reactor in Idaho. To remedy these issues, ORNL proposed construction of a general-purpose Research and Isotope Reactor, later renamed the Oak Ridge Research Reactor (ORR). It would become the first reactor facility to merge features of a low-power pool reactor and a high-power tank reactor.

A primary goal of its design was to provide easy access to the core; thus, the control-rod drives were placed beneath the reactor so experiments could be left in place during refueling. Experiment access would be through ports on multiple sides, as well as from the top through the open pool. The pool water would serve as the main radiation shielding material, with additional shielding from the reactor structure's thick concrete wall, which used high-density, high-atomic-number barytes (barium sulfate) aggregate.

Preliminary studies for the new reactor began in 1951 and paved the way for the Atomic Energy Commission (AEC) to authorize the project in 1953. The McPherson Company of Greenville, South Carolina designed the building, reactor shielding structure, and cooling system. Plans for shielding depended upon calculations based on measurements taken at the Bulk Shielding Facility, as the core of the ORR and the Bulk Shielding Facility's general design were quite similar. The proposed shield design—comprising water (like the Materials Testing Reactor and Bulk Shielding Reactor designs), barytes concrete, lead, and iron—theoretically limited the radiation levels in the building to less than one-tenth the accepted biological tolerance, excepting the sub-pile room.

The early plans for the Research and Isotope Reactor building anticipated a 75-ft cube, but as plans progressed and the AEC gained insight from operation of the Materials Testing Reactor and other reactors, the ORR underwent a number of design changes and upgrades that ultimately doubled the building footprint. By 1953, ORNL scientists presumed the ORR would eventually attain power levels of 30 MW and, to curb future expenses, suggested the appropriate shielding for 30 MW operation be installed during construction. The cooling system planned at that time only permitted a maximum of 5 MW operation, on the assumption that it would be updated later. In 1954, staff determined that evolving research needs warranted changes to the facility and an increase in the power level to 20 MW.

The construction contract was awarded to Blount Brothers Construction Company of Montgomery, Alabama, and construction began in summer 1955 (Fig. 1). The O. G. Kelley Company of Johnson City, Tennessee fabricated the two-piece aluminum reactor vessel, and ORNL modified it in 1957 to add openings for the ongoing Army Package Power Reactor Project.

After July 1957, ORNL began training personnel inside the building. The Operations Division conducted flushing and cleaning tests on the water systems, including the reactor cooling system, pool system, and primary system bypass circuits. These initial procedures revealed the need for several changes, primarily to allow for fully remote operation and increased efficiency. The reactor was completed near the end of 1957 at a cost of $4.7 million ($51.1 million in 2023 dollars). Criticality was achieved on March 21, 1958, and in early summer the AEC authorized routine operation at power levels up to 30 MW. The reactor operated at 20 MW until mid-1960, when a new cooling system was installed and the power level was increased to 30 MW.

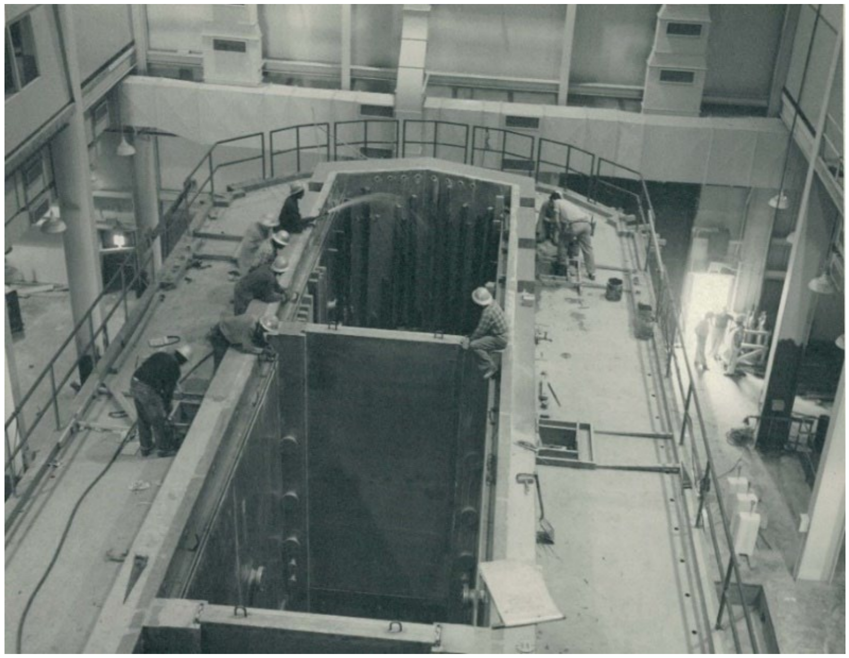

Fig. 1. Construction of Bldg. 3042 showing the three pools in the reactor structure, 1957.

Building 3042 (Fig. 2) comprises three rectangular box-shaped sections with varying roof heights that together cover an area 111 ft long by 103 ft wide on a poured-concrete foundation. It is set into a hillside; thus, the first-floor level is below grade. Beneath the first floor is a full basement that extends 20 ft below the first floor. The central portion of the building, also referred to as the crane bay or high bay, is 60 ft wide × 108 ft long and rises 59 ft above grade on the west elevation and 71 ft on the east elevation. The north and south service wings, or low bays, are each three stories high, measuring 20 ft wide and 36 ft from the first floor to the roof beams. A few minor additions were made to the exterior of the building after construction was completed in late 1957, expanding the original building's 30,700 ft^2 of floor space to a final interior footprint of about 37,370 ft^2.

The first floor was dominated by the lower level of the reactor and a truck entry. The central portion of the second floor was devoted primarily to the reactor facility, with an alley adjacent to the service entry on the west end to allow trucks to maneuver into and out of that part of the building to deliver experimental materials. The third floor of the high bay accessed the top portion of the reactor. The third floors of the two wings were subdivided to provide offices, a control room, an equipment and instrument repair room in the north wing, and a row of laboratories in the south wing. Many of the walls surrounding auxiliary rooms on the second and third floors were comprised of removable metal partitions. These permitted area enclosure rearrangements to suit future work spatial needs. Such partitions were utilized around offices, the control room, and the equipment and instrument repair room, both in the laboratory wing and the control room wing. A bridge spanning the width of the pool section could be moved along the east–west axis. Just below the top of the reactor structure was a balcony. Changes were made over the years to facilitate remote fuel and experiment handling and to improve the water cleanup systems.

Fig. 2. The west and south elevations of Bldg. 3042, circa 1960.

The reactor apparatus was contained within a multistory concrete structure that projected into the center of the building like the prow of a ship (Fig. 3). The reactor core was arranged in a 7 × 9 lattice that contained the fuel elements, shim (control) rods, beryllium reflector pieces, and experiment pieces. The core was situated near the bottom of the reactor vessel, which was approximately 15 ft tall and 5 ft in diameter. The tank in turn was positioned within the easternmost of three rectangular pools made of reinforced barytes concrete lined with 0.25-in.-thick aluminum plate welded to an aluminum structure embedded in the concrete, filled with demineralized water. The three pools, with a total capacity of about 150,000 gallons, were each approximately the same size, 20 ft long × 10 ft wide, and consisted of the reactor pool (approximately 29 ft deep), and two storage pools (each 26 ft deep) referred to as the center pool and the west pool, all separated from each other by watertight aluminum and steel gates. Within the three pools were racks for storing partially depleted elements. Having two storage pools where fuel elements, irradiated equipment, and certain experiments could be placed made it possible to empty and clean one storage tank at a time. Around the top of the reactor structure was a parapet wall 3 ft high and 18 in. thick, and a 7-ft-wide concrete walkway. A bridge spanning the width of the pool section could be moved along the east–west axis (see Fig. 4). Just below the top of the reactor structure was a balcony. At the ceiling, spanning the 60 ft width of the high bay, was a 20-ton bridge crane with a 1-ton auxiliary hoist.

Fig. 3. The Bldg. 3042 high bay, circa 1967, showing the ORR with its four working levels for research and isotope production.

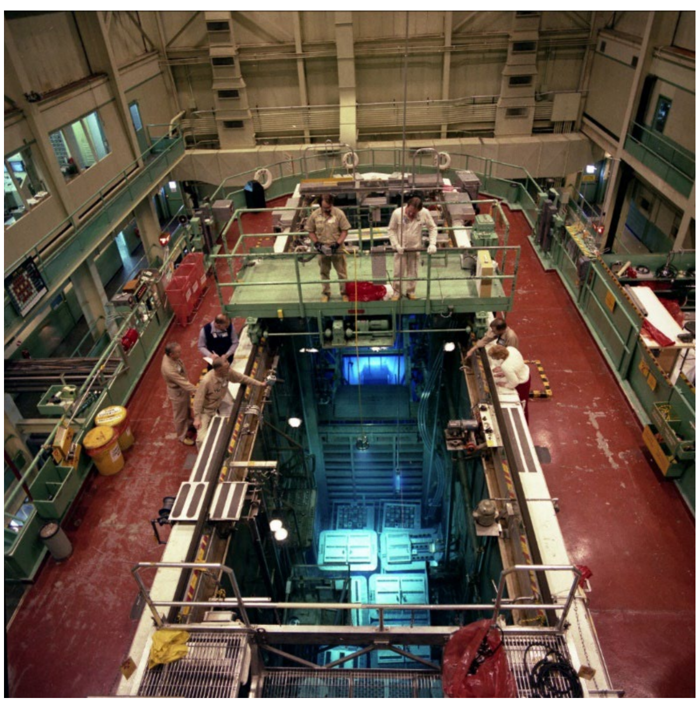

Fig. 4. Employees working from the top of the ORR structure and pool, circa 1983. Note the reactor core's "blue glow" due to Cherenkov radiation.

The elongated shape of the reactor structure and the use of water as a radiation shield and cooling/moderating feature were intended to accommodate the maximum number of experiments, which could be inserted from several sides as well as through the top of the tank. The originally planned experiment facilities included 10 beam holes, eight through-facility holes, and two instrument channels (Fig. 5). Ultimately, there were four general types of experiment facilities around the perimeter of the reactor structure: 1) six horizontal beam hole facilities that penetrated the east biological shield and terminated inside the reactor vessel at the core housing, used primarily for semipermanent experiments involving the irradiation of small samples; 2) for more substantial engineering experiments pertaining to reactor fuel research, two large ports known as the North and South Engineering Test Facilities, approximately 25 in. × 19 in., which penetrated to the core housing on the north and south sides; 3) the flat poolside face, which permitted access to the core region outside the reactor vessel on the west side; and 4) in-reactor positions, access to 10 of which was gained through flanges in the reactor tank top.

A hot cell above the end of the west pool was arranged to permit the transfer of samples and experiments from the pool for inspection. The hot cell was divided into two sections, each of which had walls of dense barytes concrete 3.5 ft thick designed to shield 10 million curies of Co-60 or the equivalent to maintain the radiation level outside the cell at less than 5 milliroentgens per hour.

The Poolside Facility, on the flat side of the reactor tank and directly adjacent to the reactor core, was the most accessible facility. It was generally used for materials damage studies and, later, gas-cooled capsule studies. Also referred to as the Poolside Capsule Facility, this high-flux facility provided ample space for large experiments requiring a high neutron flux density. Due to its location within the pool, experimenters were afforded great visibility and flexibility of movement.

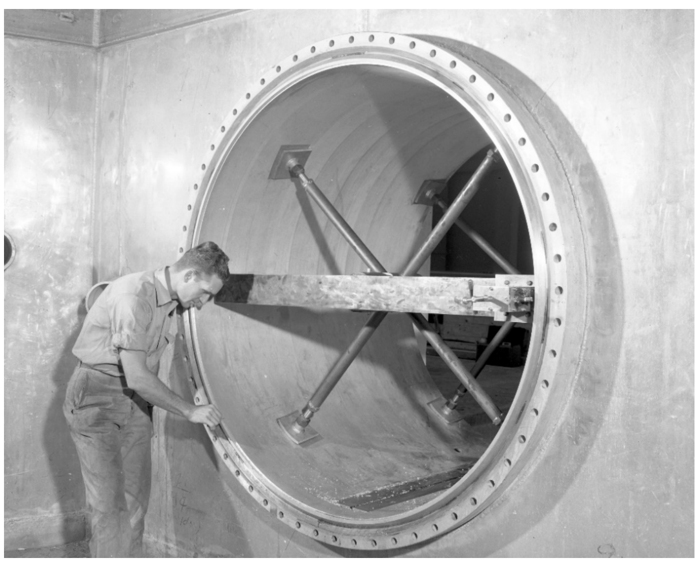

Fig. 5. The exterior of one of the ORR large engineering test facilities while under construction, circa 1957.

In comparison to its neighbors, the ORR offered the highest neutron flux and was therefore best suited for experiments pertaining to neutron scattering and diffraction studies. The high neutron flux also allowed for candidate fuel investigations and the production of high-specific-activity radioisotopes. Coupled with the high-flux characteristic, the flexibility of the pool allowed for precise control of the radiation the experiment experienced and longer-term experiment schedules were feasible given the ease of refueling the reactor without disturbing existing experiments. The ORR's neutron flux was exceeded by the High Flux Isotope Reactor in the mid-60s.

Despite its high power, the ORR did not have a hermetically sealed containment building. Instead, the building was designed to be semi-airtight, with hydraulic or pneumatic door-closing devices on all pedestrian and service entries. To comply with AEC requirements to contain gaseous fission products in the event of an accident, the building was operated at a slight negative pressure and the air treated by a scrubbing and filtration system prior to its discharge from the Bldg. 3039 stack.

In 1987, in the wake of the incidents at Three Mile Island and Chernobyl, the U.S. Department of Energy shut down all of ORNL's nuclear reactors for review. ORNL subsequently chose to retire the ORR. At that time all reactor fuel, shim rods, and beryllium were removed, and the hot cells were cleared of equipment by the end of the decade. Material remaining in the reactor pool was removed in the mid-2010s and the pool was capped with concrete shielding panels prior to draining the water. Building 3042 is currently awaiting demolition (Fig. 6).

Fig. 6. The west elevation of Building 3042, circa June 2021.

The ORR (Fig. 7) was notable as the first of a class of reactors to combine a high-energy reactor with the easy access to the reactor core more typical of a low-power swimming pool reactor, such as the Bulk Shielding Reactor. It provided the scientific community with a flexible and high-power reactor in a convenient location for research and experimentation. With a neutron flux 300 times greater than that of the ORNL Graphite Reactor, the ORR made possible more complex and fundamental neutron experiments. It inspired the construction of similar reactors in Sweden, South Africa, France, and the Netherlands. Throughout its nearly 30 years of operation, the ORR contributed to advances in numerous fields of science, including neutron scattering, reactor engineering, basic and applied physics, metallurgy, chemistry, and biology; as well as highly sensitive crime studies for the Federal Bureau of Investigation. In addition, it held the status of being the principal supplier of radioisotopes to what was then termed the "free world." During the first quarter of 1950, just over 50% of the domestic shipments to users outside the AEC were distributed for cancer-related work, with production fees waived. ORNL research divisions making use of the facility included the Isotopes, Chemical Technology, Chemistry, Solid State, Metallurgy, Reactor Projects, Reactor Chemistry, Physics, Reactor Experimental Engineering, Analytical Chemistry, Metals and Ceramics, and General Electric Divisions.

Fig. 7. ORNL Director Alvin Weinberg (third from left) provides a tour of the ORR to then Massachusetts Senator John F. Kennedy (second from left), Tennessee Senator Albert Gore, Sr. (third from right), and Jacqueline Kennedy (second from right), circa February 1959.