Contract Publication Series 21-134

NHPA SECTION 106 RECORDATION OF BUILDING 3042, THE OAK RIDGE NATIONAL LABORATORY RESEARCH REACTOR, OAK RIDGE, TENNESSEE

by
Sarah Anderson, MA,
Jenny Andrews, MA, and
Elizabeth Heavrin, MHP

Prepared for

United Cleanup Oak Ridge LLC

On behalf of
US Department of Energy

July 2022

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On behalf of the Department of Energy

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July 2022

Lead Agency: U.S. Department of Energy

TABLE OF CONTENTS

LIST OF ACRONYMS

AEC – Atomic Energy Commission

ANL – Argonne National Laboratory

ANP – Aircraft Nuclear Propulsion (Program/Project)

ARE – Aircraft Reactor Experiment

BSF – Bulk Shielding Facility

BSR – Bulk Shielding Reactor

CRA – Cultural Resource Analysts, Inc.

DOE – Department of Energy

EGCR – Experimental Gas-Cooled Reactor

ETTP – East Tennessee Technology Park

GCR – Gas-Cooled Reactor

GCR-ORR – Gas-Cooled Reactor-Oak Ridge National Laboratory Research Reactor (Loop)

HB – horizontal beam hole (facility)

HEU – highly-enriched uranium

HFED - High-Uranium-Loaded Fuel Element Development

HFIR – High-Flux Isotope Reactor

HPP – Historic Preservation Plan

HPRR – Health Physics Research Reactor

HRE – Homogeneous Reactor Experiment

IDP – Isotope Distribution Program

Kw – Kilowatt

LEU – Low-enriched uranium

LITR – Low-Intensity Testing Reactor

MSRE – Molten Salt Reactor Experiment

MTR – Materials Testing Reactor

Mw – Megawatt

NCSASR – National Center for Small-Angle Scattering Research

NEPA - Nuclear Energy for Propulsion of Aircraft (Project/Program)

NMSR – Nuclear Merchant Ship Reactor

NRHP – National Register of Historic Places

NSF – National Science Foundation

ORNL – Oak Ridge National Laboratory

ORR – ORNL Research Reactor

OSTI – DOE Office of Scientific and Technical Information

PA – Programmatic Agreement

PCA – Pool Critical Assembly

RERTR – Reduced Enrichment Research and Test Reactor (Program)

RIR - Research and Isotope Reactor

RRD – Research Reactors Division

SANS – Small-angle neutron scattering

SNS – Spallation Neutron Source

TSR – Tower Shielding Reactor

TSR-II – Tower Shielding Reactor, new design

UCOR – United Cleanup Oak Ridge LLC

UT-B – UT-Battelle, LLC

Y-12 – Y-12 National Security Complex

INTRODUCTION

In June 2021 through May 2022, Cultural Resource Analysts, Inc. (CRA), prepared this recordation package for Building 3042, the Oak Ridge National Laboratory (ORNL) Research Reactor (ORR) in Oak Ridge, Tennessee. Completed at the request of United Cleanup Oak Ridge LLC (UCOR), on behalf of the U.S. Department of Energy (DOE), this document has been prepared to record the history and current conditions of Building 3042, which had previously been determined eligible for listing in the National Register of Historic Places (NRHP) as a contributing resource within the proposed ORNL Historic District.

Building 3042, which housed the ORR, is located approximately 80 ft north of Hillside Avenue approximately 400 ft west of its intersection with Fifth Street. The Graphite Reactor, Bulk Shielding Reactor (BSR) and Low-Intensity Testing Reactor (LITR) are all located nearby in this area south of Bethel Valley Road, north of Hillside Avenue, and west of Fifth Street in ORNL's central campus, which allowed for the efficient simultaneous operation and monitoring of multiple reactors (Figures 1 and 2). Building 3042 and the ORR were constructed between 1955 and 1958. The ORR was a water-cooled, water-moderated, enriched uranium fueled high-flux nuclear-fission reactor constructed by ORNL to fulfill research and radioisotope production needs. The ORR fulfilled this mission until ORNL retired the reactor in 1987. Building 3042 is currently vacant and awaiting demolition.

Building 3042 was included in the 1994 *Architectural/Historical Assessment of the Oak Ridge National Laboratory, Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (Carver and Slater 1994). The 1994 report recommended Building 3042 eligible for listing in the NRHP as a contributing resource in the proposed NRHP-eligible ORNL Historic District. The ORNL Historic District is eligible for listing in the NRHP under Criterion A "for its historical associations with the Manhattan Project, ORNL's development as a national laboratory within the overall post-World War II government sponsored scientific movement, and for early nuclear research," and under Criterion C "for the engineering merits of many of the properties within the proposed district and for their contributions to scientific research" (Carver and Slater 1994:355). The updated historic architectural resource survey of ORNL completed in 2018, which recommended an expanded period of significance for the ORNL Historic District, confirmed Building 3042 as a contributing resource in the proposed ORNL Historic District (Hearnes et al. 2018).

Building 3042 appears in the 2004 *Oak Ridge National Laboratory National Historic Preservation Act Historic Preservation Plan* (HPP), which identifies Building 3042 as a contributing resource in the proposed NRHP-eligible ORNL Historic District. As a tool for evaluating the contribution of each building to the historic district, the HPP utilized a graded scheme, separating buildings into three categories of significance—major, moderate, and minor—as relates to their contributions to the "Historical Integrity" of the district as well as the "Visual Appearance" of the district's cultural landscape. Building 3042 was considered to be of major historic significance (Thomason and Associates 2004:79).

The HPP identified Building 3042 as excess to mission needs and proposed demolition (Thomason and Associates 2004:82). As such, Building 3042 is addressed in the 2005 Programmatic Agreement Among the Department of Energy Oak Ridge Operations Office, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation Concerning the Management of Historical and Cultural Properties at the Oak Ridge National Laboratory (PA), which calls for the development of an interpretive plan for ORNL to provide specific detail on the interpretive efforts to be performed for those buildings of major historic significance that have been determined excess to mission needs and proposed for demolition, including Building 3042. The 2008 *Oak Ridge National Laboratory Interpretive Plan, Oak Ridge, Tennessee*, stipulates that buildings of major historic significance should be subject to an extensive interpretive effort including "a record file suitable for preservation, using video and/or CD-ROM technology containing a photo record history of each building, a collection of available building maps and drawings, and a detailed account of historic missions and activities (including interviews with former workers, if available)" (Bethel Jacobs Company, LLC 2008:23). The scope of this recordation package is designed to fulfill the requirements of the HPP, the PA, and the interpretive plan for Building 3042.

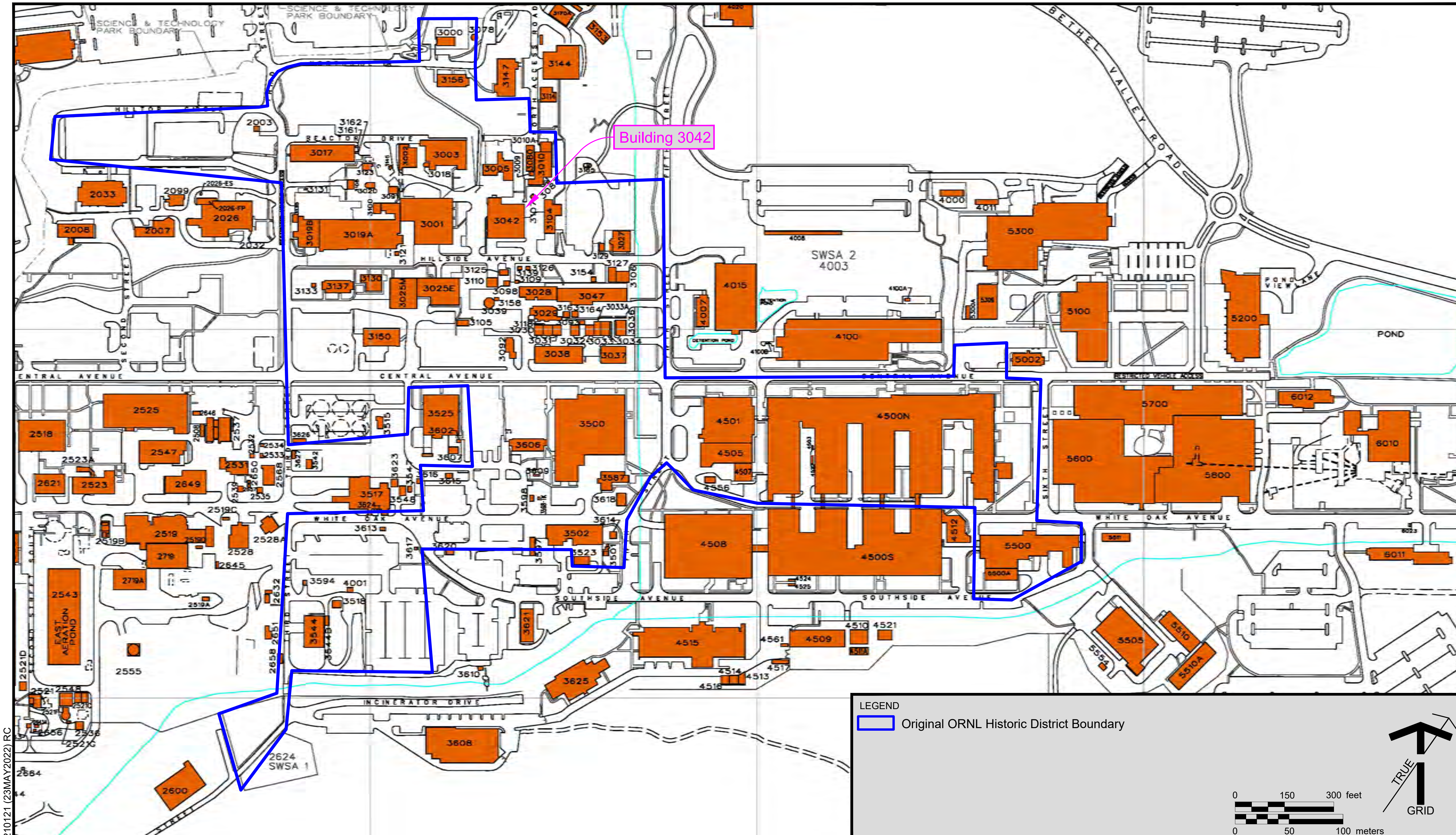

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Figure 1. ORNL site plan depicting the location of Building 3042 within the ORNL Historic District.

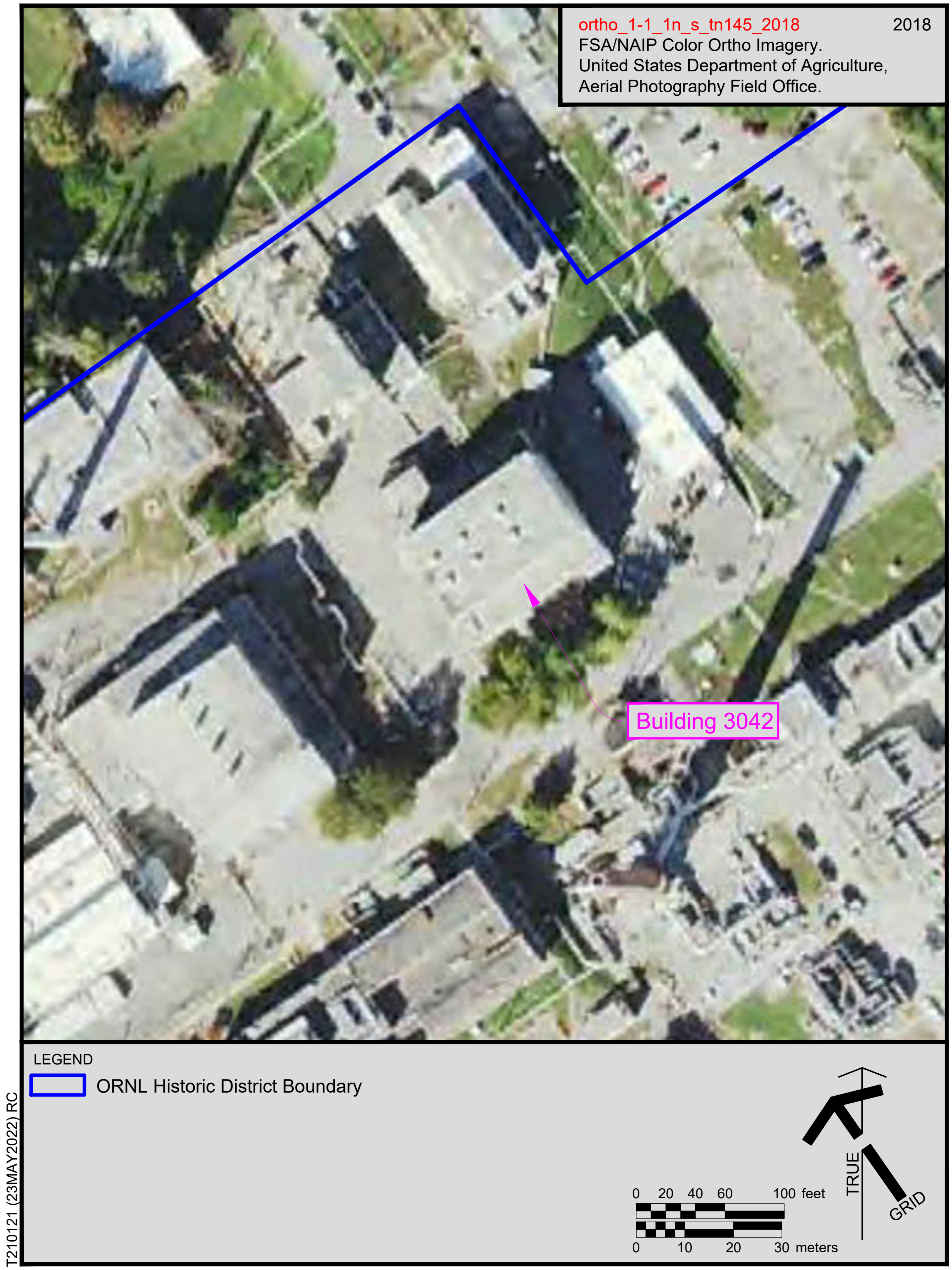

Figure 2. Aerial photograph depicting the location of Building 3042, housing the ORR.

METHODOLOGY

This recordation package represents a substantial collaborative effort among CRA's architectural historians and UCOR staff, with UT-Battelle, LLC (UT-B) staff providing additional research support. Since much of the documentation regarding Building 3042 had not been previously cleared for public release, significant initial archival research was conducted by UCOR and UT-B staff. Provided below is a description of UCOR assets searched:

**UCOR Document Management Center

**National Historic Preservation Act documentation, including building descriptions, operational histories, and proposed actions

**Current interior and exterior photographs from the UCOR decontamination and decommissioning Project Teams

Provided below is a description of additional assets searched during the exhaustive research effort conducted by Records Analyst David Whittaker:

**ORNL Laboratory Records, including technical reports, division annual and semi-annual reports, correspondence, and other facility records maintained in inactive records storage

**Technical reports, journals, electronic databases, and books from the ORNL Research Laboratory

**ORNL Photo Gallery

**ORNL Engineering Records, Mike Compton

**ORNL Photography and Reproduction, Joy Anderson

**DOE Office of Scientific and Technical Information (OSTI)

**DOE Information Center

**U.S. Department of Commerce National Technical Reports Library

**Oak Ridge Public Library

**DOE OpenNet

Prior to release to CRA, all documents were necessarily reviewed and documented as cleared for classification release, requiring coordination with the ORNL and UCOR Classification Offices.

Required physical documentation of the buildings necessitated close coordination between CRA's architectural historians and UCOR staff. For the exterior photographs, CRA's architectural historians conducted the site visit with UCOR staff members and took photographs with a UCOR camera. For the interior photographs, conditions inside the buildings and security limitations prohibited CRA historians from entering the buildings during the photography sessions. Instead, UCOR staff took all interior photographs in accordance with Health and Safety requirements defined by UCOR Work Plans. All photographs were reviewed by the UCOR Classification Office before release to CRA.

Upon approval for public release, research documents not previously available from DOE OSTI were submitted so that they could be provided for free public access through OSTI's website. UCOR will also release this recordation package through OSTI, the DOE Information Center website, and the City of Oak Ridge Public Library for free public access upon completion. Cleared and released, multiple historic primary source documents have been made available through this effort. Along with the interpretive effort culminating in this recordation document, this achievement represents significant new contributions of publicly available documentation related to Building 3042 and associated ORNL activities which are now freely available for future researchers and the interested public.

HISTORIC CONTEXT FOR BUILDING 3042

ORNL is one of three DOE facilities that compose the 33,316-acre Oak Ridge Reservation in Anderson and Roane Counties, Tennessee. The main ORNL campus occupies approximately 1,100 acres in Bethel and Melton Valleys and on Chestnut Ridge. The Oak Ridge Reservation was first developed in the early 1940s as part of the Manhattan Project, the U.S. government's top secret effort to build the first atomic bomb. The ridges and valleys of East Tennessee provided an ideal location for the construction of the nuclear research and production facilities since the area offered extensive transportation, water, and power resources, and the topography would confine the impacts of an explosion in the event of an accident. The Oak Ridge Reservation included three production facilities and the Townsite where workers lived. The area known as the Y-12 National Security Complex (Y-12) contained the electromagnetic plant, and the area known as K-25 (now East Tennessee Technology Park [ETTP]) contained the gaseous diffusion plant (Figure 3). The facility that would become ORNL was code-named X-10. The smallest of the three sites, X-10 was built between February and November 1943 at a cost of $12 million and employed a maximum of 1,513 people during the war (Johnson and Schaffer 1992a:2). Centered on the Graphite Reactor, now a National Historic Landmark, X-10's primary function was the production of plutonium. The plutonium produced at X-10 was used for research on the production of the world's first atomic bomb. After dropping the uranium gun-type atomic bomb "Little Boy" on the city of Hiroshima, Japan on August 6, 1945, the U.S. dropped the plutonium implosion-type atomic bomb "Fat Man" on Nagasaki on August 9, 1945. The bombing led to Japan's surrender and the subsequent end of World War II.

Following World War II, the Atomic Energy Commission (AEC) was formed and management of the Oak Ridge Reservation, including the X-10 installation, was contracted to private companies. In 1946, the nation's first national laboratories were established, located at Argonne, near Chicago and Brookhaven, on Long Island. Although Clinton Laboratories was not initially designated as a national laboratory, it continued to pursue research in the areas of reactor development, the production of radioactive isotopes for experimental purposes, and uranium recovery, now under the direction of Monsanto Chemical Company. Although important work was being accomplished, Clinton Laboratories struggled to define a clear mission and long-term goals during this period.

In 1948, the AEC designated Clinton Laboratories, located at the X-10 site, a national laboratory, dedicated to the pursuit of basic scientific research, isotope production, and chemical technology (Greenstreet 1992:9–10). While Argonne National Laboratory (ANL) was designated as the primary laboratory for reactor research, the Clinton National Laboratory also provided critical support in this area. In March 1948, Carbide & Carbon Chemicals Company (later Union Carbide) was hired to operate the Clinton National Laboratory, and the laboratory's name was changed to ORNL. ORNL's mission has evolved over time. Management of ORNL was transferred to Martin Marietta Energy Systems, Inc. (also known as MMES, and later known as Lockheed-Martin) in 1984, and UT-B assumed management of ORNL facilities in April 2000. Today ORNL is the largest DOE science and energy laboratory pursuing advanced research in a wide variety of disciplines, conducting science in 23 of DOE's 24 core capabilities. ORNL's mission is to deliver scientific discoveries and technical breakthroughs that will accelerate the development and deployment of solutions in clean energy and global security (Thomason and Associates 2004:33-34; Hearnes et al. 2018:11).

ORNL's Research Reactors

The historic focal point of the X-10 site was the Graphite Reactor, an air-cooled, graphite-moderated reactor constructed during the Manhattan Project to pursue the enrichment of plutonium and serve as a pilot plant for the larger plutonium production reactor being constructed in Hanford, Washington (Figures 4 and 5). The reactor "used neutrons emitted in the fission of uranium-235 to convert uranium-238 into a new element, plutonium-239" (Johnson and Schaffer 1992a:2). As Rosenthal describes,

> *The Oak Ridge pile was a 24 ft graphite cube surrounded by a 7 ft thick shield of high-density concrete. Passing through the graphite were 1248 diamond-shaped channels on 8 in centers that at criticality contained 44,000 aluminum-clad uranium 'slugs' measuring 1 in by 4 in…Passages through the front shield matched the channels through the core, and the gap between them was spanned by steel tubes. After removal of shield plugs, crews standing on an elevator at the front face pushed fresh slugs in to the core of the shutdown reactor with long rods…The irradiated slugs dropped into the air gap at the rear of the core, where a chute guided them to a 20 ft deep canal filled with water. Here they were loaded into buckets using long poles and transported underwater to a cell in the adjacent chemical processing plant* [Rosenthal 2010:3-4].

Construction of the Graphite Reactor took nine months, and criticality was achieved on November 4, 1943. Two grams of plutonium were produced in two months and shipped to Los Alamos for research in the development of a plutonium bomb. A total of 326 grams of plutonium were produced in the pile by early 1945. Meanwhile, the Graphite Reactor also was used for a variety of experimental purposes in support of the Manhattan Project mission, including "to determine the effects of radiation on materials to be used at Hanford, to measure cross sections and fission product yields and half-lives, to irradiate mice to determine health effects, and to conduct other urgent tests" (Rosenthal 2010:7). In 1945, the Graphite Reactor was used to produce large quantities of radioactive lanthanum, known as RaLa, for flash radiographic measurements of implosions during testing at Los Alamos, marking the first large-scale production of radioisotopes (Rosenthal 2010:7).

In December 1944, its initial war-time mission complete, the Graphite Reactor complex began to transition from plutonium production to experimental research in the emerging field of nuclear science and technology (Greenstreet 1992:2). After conclusion of the war, as Clinton Laboratories charted its uncertain future, Eugene Wigner of Princeton University took a year's leave to serve as research and development director of the laboratory. Wigner was a pioneering chemical engineer and physicist from Budapest who came to the United States in 1930. He was one of the first scientists in America to recognize the danger of Germany's discovery of nuclear fission in uranium in 1939, urging Albert Einstein to alert President Franklin Roosevelt of the urgency of the matter, which led to the U.S. government's entry into nuclear energy research and the creation of the Manhattan Project. He headed the theoretical physics group that met at the University of Chicago to develop designs for nuclear reactors in the early days of World War II, and later joined the X-10 staff (Johnson and Schaffer 1992a:4, 6-9). In his role as research director at Clinton Laboratories, Wigner's central goals were "developing a high-neutron-flux reactor for testing materials and a gas-cooled Daniels Pile for demonstrating the use of nuclear energy for electricity production" (Johnson and Schaffer 1992b:33).

Alvin Weinberg, who worked with Wigner in Chicago, arrived in Oak Ridge in 1945. Upon Wigner's departure in 1948, Weinberg became Research Director at ORNL. He would later serve as Director of ORNL, a position he held for several years. From the beginning of his tenure as Research Director, Weinberg continued Wigner's mission to develop new reactors in Oak Ridge. Despite AEC's initial policy that reactor development would be focused at ANL, it soon became clear that centralization of reactor development was impractical. While the Daniels Pile project was abandoned, ultimately a team of scientists from both ANL and Clinton National Laboratories were involved in the development of a high-flux experimental reactor known as the Materials Testing Reactor (MTR), to be built at the recently-acquired Nuclear Reactor Test Site in Idaho. A full-scale mockup of the reactor was designed, constructed, and tested at ORNL. Although originally intended only as a prototype, the reactor, later known as the LITR, was subsequently approved to serve as ORNL's second research reactor (Thompson 1963:57-67).

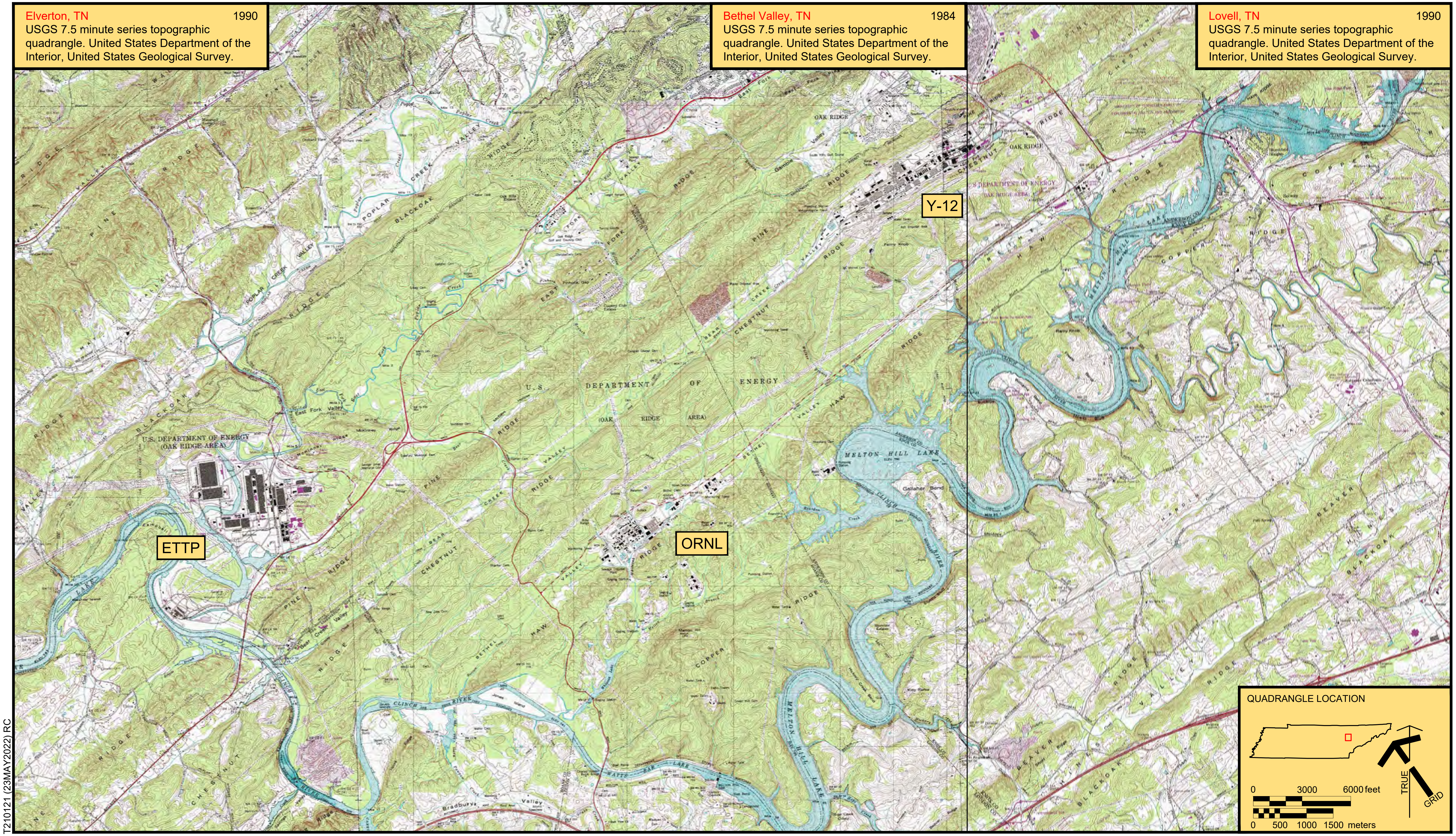

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Figure 3. Topographic map depicting the locations of ORNL, Y-12, and ETTP.

Figure 4. The Graphite Reactor in 1947 (DOE Oak Ridge Operations Photo 3537).

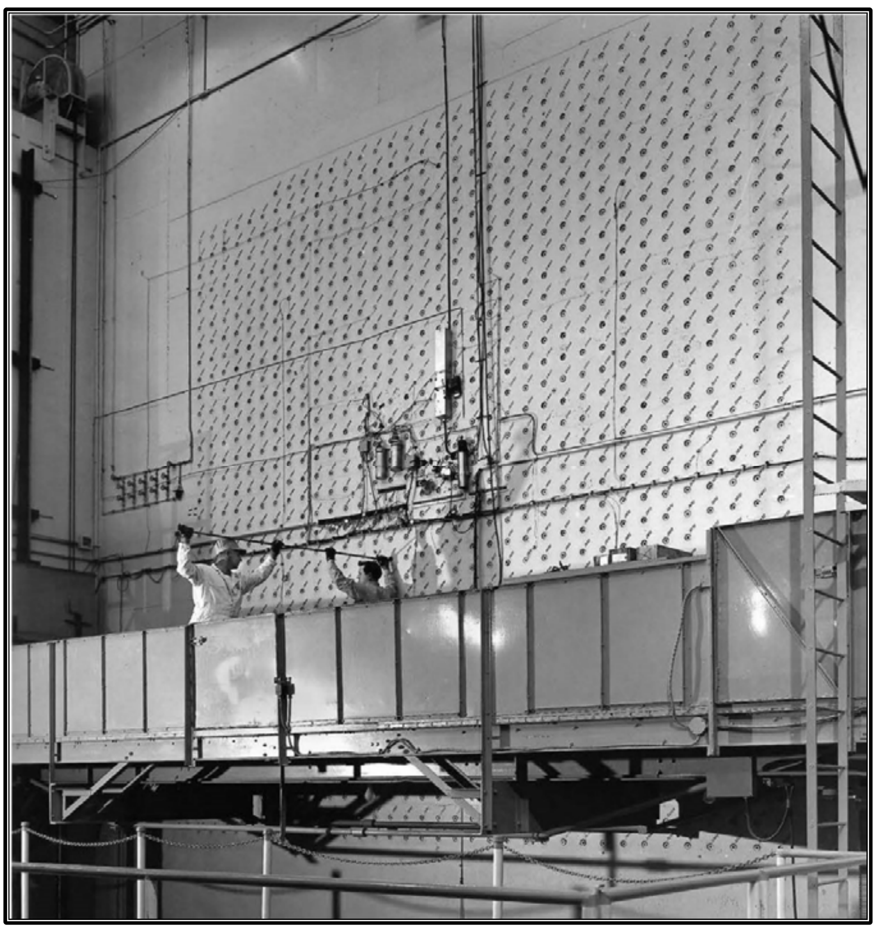


Figure 5. Loading fuel into the Graphite Reactor (ORNL History Photo 69).

The design for the MTR was conceptualized by Wigner and developed in the post-war period by him and Weinberg. Wigner's concept utilized "a high-powered enriched-uranium core cooled and moderated by ordinary water. Fast neutrons would escape from the core and be slowed down and 'trapped' in a surrounding beryllium reflector, thereby producing a high-flux of slow neutrons" (Rosenthal 2010:39). Wigner developed the fuel elements for the MTR, composed of curved sheets of a uranium/aluminum alloy attached to a rigid unit, which would become a model used in most of the world's research reactors, including the ORR at ORNL. Although Wigner returned to Princeton in 1947, work on the MTR continued at Oak Ridge. Weinberg successfully resisted the AEC's efforts to move the entirety of the project to ANL, and received permission to construct a full-scale mock-up. ORNL progressively convinced the AEC to allow the installation of real fuel elements, the addition of shielding and a heat exchanger, and, finally, operation at powers up to 1500 kilowatts (kw) (later 3 megawatts [Mw]). This reactor became known as the LITR and continued operation at ORNL until 1968 (Rosenthal 2010:39-42). The impact of the MTR design first developed by Wigner and Weinberg was enormous. The majority of ORNL's research reactors, and indeed many of the research reactors built around the world, were water cooled reactors developed from the model of the MTR. Weinberg's persistence in keeping a large portion of the MTR project at ORNL, rather than allowing its removal to ANL, also had significant implications for the history of the national laboratory, laying the groundwork for a robust reactor program in the subsequent decades.

The 1950s were the heyday of fission reactor development. Building upon the success of the MTR/LITR, and often adapting elements from its design, the number of nuclear reactors designed or built at ORNL during that decade outpaced all other decades combined, including the Homogeneous Reactor Experiment (HRE), Aircraft Reactor Experiment (ARE), Molten Salt Reactor Experiment (MSRE), BSR, Army Package Power Reactor (also known as the APPR), Experimental Gas-Cooled Reactor (EGCR/GCR) Program, Tower Shielding Reactor (TSR), and the ORR (Jefferson 1993:7). The ORR, approved for construction in 1953, integrated characteristics of both the BSR and the MTR, providing an initial power level of 20 Mw (later 30 Mw) and a "neutron beam intensity so critical for research" (Johnson and Schaffer 1992d:104).

To further support its growing research programs in the 1950s, ORNL gained AEC approval to build a new high-flux reactor based on the MTR model. Completed in 1958, the ORR was constructed in ORNL's central campus near its other research reactors. Like LITR and BSR, the ORR was another water-cooled reactor, but it was capable of operating at much higher power than ORNL's other research reactors (30 Mw, compared to the Graphite Reactor's 3.5 Mw, LITR's 3.0 Mw, and BSR's 2.0 Mw). "The ORR was the first of a class of reactors which combined the features of both the pool-reactor and tank-reactor types" (Tabor and Costner 1962:1). Completed in 1958, the ORR was 100 times more powerful than the Graphite Reactor and operated at a higher power-level than any other reactor at ORNL in the late 1950s. The ORR contributed to numerous programs at ORNL, including the exploration of potential reactor engineering designs. Similar to the central mission of the MTR, the neutron beams of the ORR subjected materials, particularly fuel, to intense radiation in order to screen candidate nuclear reactor materials (Johnson and Schaffer 1992b:33-34, 1992d:104; Cabage 2000:4). The ORR was a versatile research reactor that served ORNL for 29 years, supporting "neutron scattering research, fundamental investigations of the behavior of metals and ceramics under radiation, and the testing of materials for reactor fuel elements and for fusion devices. It also became the major world supplier of radioisotopes" (Figures 6–8) (Rosenthal 2010:54). The ORR would be superseded by the High-Flux Isotope Reactor (HFIR) upon its completion in the mid-1960s.

Other reactors pursued at ORNL included the Pebble-Bed Reactor (also known as the PBR), Liquid Metal Fast Breeder Reactor (also known as the LMFBR), and the Support Nuclear Power Source (also known as the SNAP) program for National Aeronautics and Space Administration vehicles. In the 1960s and 1970s research was also conducted into the feasibility of pairing a nuclear reactor with a desalination plant, to provide irrigation water for agricultural operations and community development.

While some of these reactors were built as experiments to advance the field of nuclear reactor development or serve as prototypes for other reactors built elsewhere, others were built as, or later became, research reactors utilized for a wide-range of scientific research at ORNL for several years or even decades.

From the creation of Clinton Laboratories, reactor development fell under the purview of the Engineering Development Division, later renamed the Reactor Technology Division, which subsequently separated into the Reactor Experimental Engineering Division and the Aircraft Nuclear Propulsion (ANP) Division (Greenstreet 1992:15). The Reactor Experimental Engineering Division was initially concerned primarily with aqueous homogeneous reactors for power production and for generating fuel through breeding, and the ANP was focused on the development of reactors for military use. In 1960 the two divisions were recombined into the Reactor Division. In 1977 the Reactor Division was renamed the Engineering Technology Division. Meanwhile, the ongoing operation of ORNL’s research reactors was the responsibility of the Operations Division and its Reactor Operations Department. In 1987, in accordance with new DOE directives following the Three Mile Island and Chernobyl incidents, the Research Reactors Division (RRD) was created as a separate division to oversee reactor operations / serve this purpose (Stapleton 1993:7–9).

Figure 6. Archival photograph, circa 1967, showing the ORR structure in the high-bay of Building 3042 (ORNL Photo 86784).

Figure 7. Archival photograph, circa 1956, showing Building 3042 under construction, facing northwest (ORNL Photo 56-1398).

Figure 8. Circa 2003 photograph showing Building 3042 facing northwest (ORNL Photo 4233-2003).

Several of the reactor projects of the 1950s were initially constructed in support of the ANP Program, a substantial research collaboration between the AEC and the U.S. Air Force to develop a nuclear-powered aircraft capable of flying at least 12,000 mi at 450 miles per hour without refueling in order to deliver nuclear bombs anywhere in the world (Johnson and Schaffer 1992c:66). Although the primary goals of the project were never realized, funding for the ANP Program supported a substantial portion of ORNL's research efforts in the 1950s, contributing to the growth and success of the national lab and leading to significant discoveries in multiple fields of science.

Much of ORNL's initial research for the ANP focused on the development of lightweight shielding to protect airplane crews and sensitive aircraft components from radiation. When an assembly attached to the Graphite Reactor proved inadequate to support this research, the AEC approved development of the BSR, a small, inexpensive reactor using MTR-type fuel elements installed in a "swimming pool" to provide core cooling, neutron moderation, and easy maneuverability to test bulk shielding in various configurations (Johnson and Schaffer 1992c:70). The BSR's usefulness extended far beyond its applications to the ANP Program, long serving ORNL as a research reactor and an important educational tool. Its inexpensive, safe, and stable design was replicated at numerous universities and research laboratories around the world.

The ANP Program also led to the development of the TSR and ARE at ORNL. The Tower Shielding Facility, completed in 1953, featured the 1-Mw TSR suspended in a spherical container between four tall towers, allowing for experiments regarding radiation exposure and shielding requirements for a reactor flying overhead in a nuclear aircraft (Johnson and Schaffer 1992c:71). A more powerful reactor, the TSR-II, replaced the original in 1958. Both the TSR-I and TSR-II were water-cooled reactors using MTR-type fuel plates. After termination of the ANP Program, the TSR remained a very important research reactor for ORNL, providing unique capabilities in testing reactor shielding technologies (Stapleton 1993:38). The ARE, on the other hand, was designed to demonstrate the potential of a small reactor fueled by molten uranium salts to power an aircraft engine. Its successful run in October 1954 led to the development of a larger prototype, called the "fireball reactor," to conduct more sophisticated experiments regarding the functioning of such a reactor on an operating aircraft (Johnson and Schaffer 1992c:72-73). The successful use of molten-salt fuel in the ARE led to the development of the MSRE in the 1960s (Rosenthal 2010:29). Other significant contributions to ORNL under the ANP Program included the construction of a critical experiments facility to test reactor fuels and a physics laboratory to study the effects of radiation on solid materials, acquisition of nuclear particle accelerators and digital computers, and the successful merger of the ORNL and Y-12 research divisions in support of common research goals (Johnson and Schaffer 1992c:73).

In the post-war period, the U.S government also pursued the design of a nuclear powered submarine, an undertaking which would prove successful. While the Naval Nuclear Propulsion Program was not based at ORNL, Captain Hyman G. Rickover, who spearheaded the program for over 34 years, initially spent a year at ORNL learning the fundamentals of nuclear reactor technology, which would lay the foundation for the pressurized-water reactor design that was ultimately utilized by the Navy. Research at ORNL, including the development of MTR and research utilizing the LITR, BSR, and ORR, and the work of technical staff trained there, were essential to the ultimate success of the program (DOE and Department of the Navy 2015:17–18).

While the aircraft and naval nuclear propulsion programs pursued new military applications of nuclear power, in 1953 President Dwight Eisenhower made a speech to the United Nations that became known as the "Atoms for Peace" speech, in which he dedicated the United States "to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life." In 1954, Eisenhower signed the Atomic Energy Act, which encouraged cooperation between the AEC and private industry in developing nuclear power, leading to the declassification of much nuclear science data (Johnson and Schaffer 1992d:97). Continuing this momentum, in 1955 the United Nations hosted the first International Conference on the Peaceful Uses of Atomic Energy in Geneva, resulting in enormous exchange of previously secret information in the field of nuclear science and technology. One of the highlights of the event was an actual operating reactor that was designed, built, and tested at ORNL and shipped to Geneva where it was demonstrated for conference attendees. Known as the Geneva Reactor or "Project Aquarium" (for its swimming pool design), it was a near-replica of ORNL's BSR, except for the fuel used. Since highly-enriched uranium (HEU) could not be transported out of the country, the Geneva Reactor was designed to operate using low-enriched uranium (LEU) in an aluminum matrix. After being seen by thousands in Geneva, the reactor's simple design and operation and its more accessible fuel source made it a prototype for private research reactors used across the world (Rosenthal 2010:45; Johnson and Schaffer 1992d:107–108).

The 1960s saw the construction of the two final research reactors at ORNL. Both were constructed in secluded areas south of the central ORNL campus. The Health Physics Research Reactor (HPRR) was a fast burst reactor that was completed in 1961, utilized at the Nevada Test Site for two years, and then permanently installed at ORNL's Dosimetry Applications Research Facility (also known as the DOSAR) in 1963. Distinct from ORNL's other research reactors, the HPRR was designed to produce a wide range of dose rates of radiation (including bursts of up to 1016 to 1017 fissions in pulse mode) to study the effects of various types of exposures on plants, animals, and the human body. In use from 1963 to 1987, HPRR's most valuable contribution was in helping establish safe radiation exposure limits (Rosenthal 2010:35-38).

The HFIR was constructed in Melton Valley south of the central ORNL campus from 1961 to 1965. HFIR is a very high-flux reactor capable of producing californium and other transuranium isotopes for use in research, industrial, and medical applications, as well as high-flux neutrons for research. Building upon but departing in some respects from the earlier MTR model, "HFIR is a beryllium-reflected, light water-cooled-and-moderated, flux trap reactor that uses highly enriched 235U as the fuel" (Stapleton 1993:44). Following several shutdowns in the 1980s to address various issues, today HFIR is ORNL's only operating research reactor (Rosenthal 2010:59).

The Graphite Reactor was shut down in 1963 after 20 years in service, and LITR was shut down in 1968 "in part because of funding restraints and in part because they were superseded by other reactors (Rosenthal 2010:8). The ORR and HFIR offered much higher-powered options for research and radioisotope production, successfully building upon many of the principles established by Wigner and Weinberg in design of the MTR.

In the 1980s, ORNL's research reactors came under scrutiny in the wake of the incidents at Three Mile Island and Chernobyl. In March 1987, the DOE, the federal agency responsible for ORNL since it was created by the DOE Act in 1977, shut down all of ORNL's nuclear reactors for review and improvement of management and procedures. The RRD was established on April 6, 1987, to provide a group solely devoted to operation and oversight of ORNL's research reactors. A.L. "Pete" Lotts was named director, and several new sections were created to oversee various aspects of the reactor program. Originally located in several buildings, the new division was later consolidated near the HFIR site. Ultimately, only the HFIR and TSR–II resumed operation after 1987. The HPRR, BSR, and ORR ran for the last time in 1987; TSR-II was shut down in 1992 (Stapleton 1993:9–13). ORNL's research reactors leave an impressive legacy, having been utilized by countless ORNL scientists, national and international researchers, and students to conduct work that significantly advanced our understanding of nuclear science and technology, and serving as prototypes for other research reactors constructed across the globe. Today the HFIR continues to attract scientists to ORNL from around the world to make use of its power and diverse capabilities.

BUILDING 3042

Architectural Description

Building 3042 housed the ORR, which was notable for its integration of a high-energy reactor with the easy access to the reactor core more typical of a low-power "swimming pool" reactor, such as the BSR. The reactor apparatus of the ORR was submerged in a large pool of demineralized water contained within a multi-story concrete structure that projected into the central portion of the building like the prow of a ship (Figures 9 and 10). The building surrounding the reactor structure is boxlike, essentially rectangular, multi-level, and four stories at its maximum, with one story being a full basement, built into the side of a hill so that the first floor is below grade (Figure 11). The central or high-bay portion of the building is the tallest section, flanked by two lower sections or wings. The location of the building, just east of the Graphite Reactor (Building 3001), was chosen primarily to take advantage of nearby existing facilities that could be shared, such as a ventilation stack. Additionally, reactor staff could be used efficiently across multiple reactor facilities in the same vicinity.

Initially referred to as the Research and Isotope Reactor (RIR), the facility was intended to expand the potential for isotope production and for research activities related to physics, chemistry, biology, and reactor development beyond the existing capacity of the ORNL Graphite Reactor, and to provide a more convenient and versatile reactor than the high-flux MTR located near Arco, Idaho (Snell and Weinberg 1950:4). The design of the ORR incorporated aspects of other reactors, but was considered a unique concept in that it combined a high-flux reactor with the ready access to the core lattice more typical of low-power "swimming-pool" reactors, such as the BSR. The ORR could be accessed through multiple experiment ports located on the sides of the reactor structure, as well as through the top of the pool. The reactor's flexibility could thus accommodate multiple experimental facilities that could be easily changed out (Hamrick and Swanks 1968:98–99). During the reactor's nearly 30 years of operation, a number of ORNL research divisions made use of the facility for a variety of experiments, including 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 (Casto 1959:11; Tabor and Hurt 1967:28–35).

Circa 1950, ORNL produced early plans for the RIR/ORR, anticipating a building that was cube-shaped, with a square footprint of 75 ft by 75 ft, and a ceiling height of approximately 75 ft (Figure 12) (Snell and Weinberg 1950:31, 43). As plans progressed and the AEC gained insight from operation of the MTR and other reactors, the design of the ORR underwent a number of changes and upgrades (Cole and Gill 1957:2). ORNL submitted a preliminary proposal for the ORR in early 1954, suggesting a 5-Mw facility similar in design to the MTR. Later that year, staff reviewed the project plans and determined that evolving research needs at the Laboratory warranted changes to the facility and an increase in the power level to 20 Mw, resulting in design modifications in early 1955 (Hamrick and Swanks 1968:1). The Laboratory again upgraded the facility to operate at 30 Mw by July 1960 (Tabor and Costner 1962:3).

The McPherson Company of Greenville, South Carolina designed the building, reactor shielding structure, and cooling system and the construction contract was awarded to Blount Brothers Construction Company of Montgomery, Alabama. Construction of Building 3042 began in 1955 (Cole and Gill 1957:3). The O. G. Kelley Company of Johnson City, Tennessee fabricated the two-piece reactor vessel, comprised of the reactor tank and reactor tank top. ORNL personnel modified the reactor vessel based upon facility needs and requested specifications determined during Laboratory meetings while the building was under construction. The entire facility was completed and the reactor vessel was installed in early 1958, with criticality achieved shortly thereafter on March 21, 1958, and operation at 20 Mw of power initiated in April (Figure 13) (Carver and Slater 1994:231; Tabor and Costner 1962:3; Wright 1956:3, 7; Cagle 1959:14; Cole and Gill 1957:3-4; Gill and Cole 1956:2-5). Archival photographs show the progression of the building's construction from July 1955 through June 1958 (Figures 14–21).

Figure 9. Current photograph of the reactor facility in the high-bay section of Building 3042, facing northwest.

Figure 10. Circa 1958 photograph of the reactor facility in the high-bay section of Building 3042, facing southwest. A life preserver, marked with "S. S. ORR," is affixed to the balcony railing at top (ORNL Photo 43965).

Figure 11. Current photograph of the exterior of Building 3042, facing northeast.

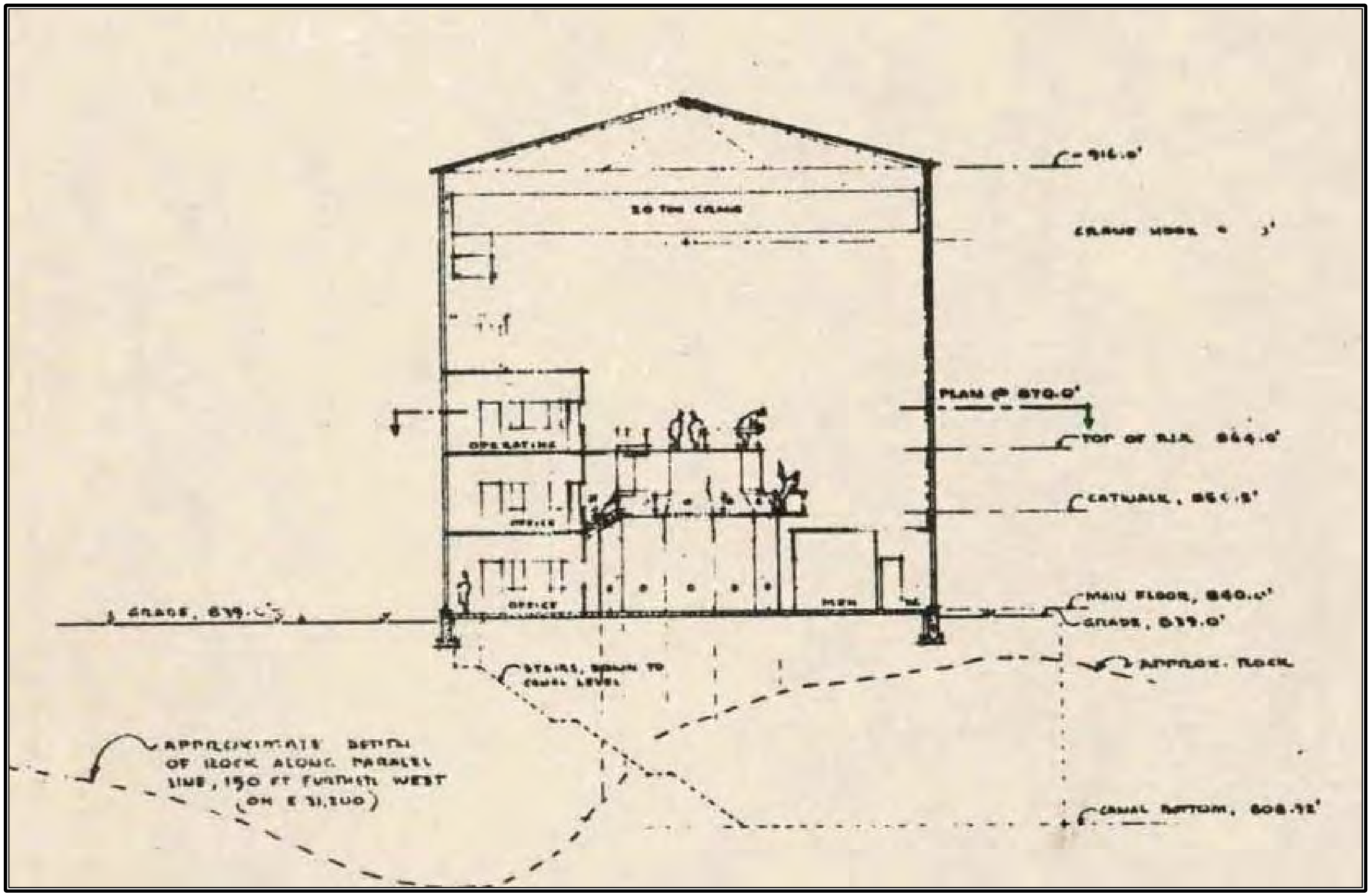


Figure 12. Portion of architectural drawing (D-8187) showing preliminary design for a building to house the ORR, then called the RIR, circa 1950 (Snell and Weinberg 1950:43).

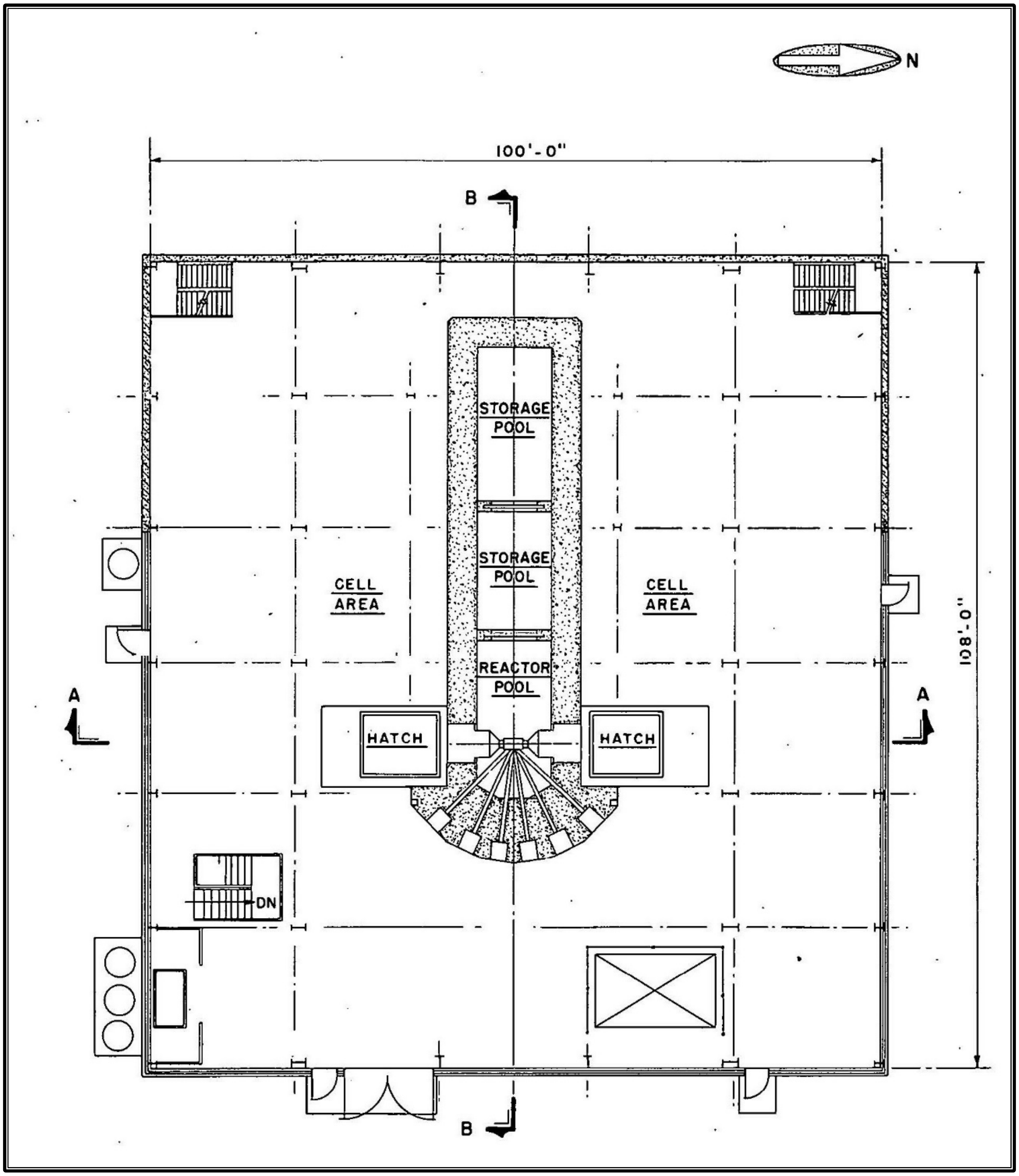


Figure 13. Architectural drawing (C-11392) showing the first floor plans for Building 3042, circa 1956 (Wright 1956:7).

Figure 14. Archival photograph of the construction of Building 3042 showing the initial excavation of the site, September 23, 1955 (ORNL Photo 55-0836).

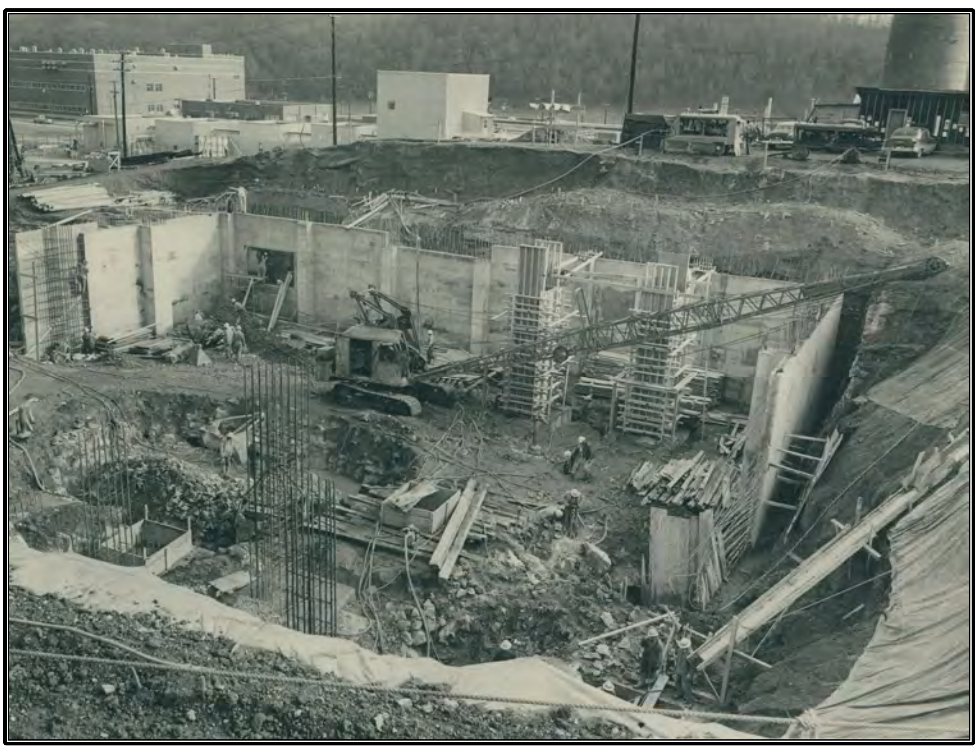


Figure 15. Archival photograph of the construction of Building 3042 showing the early stage of the foundation, December 19, 1955 (ORNL Photo 55-1192).

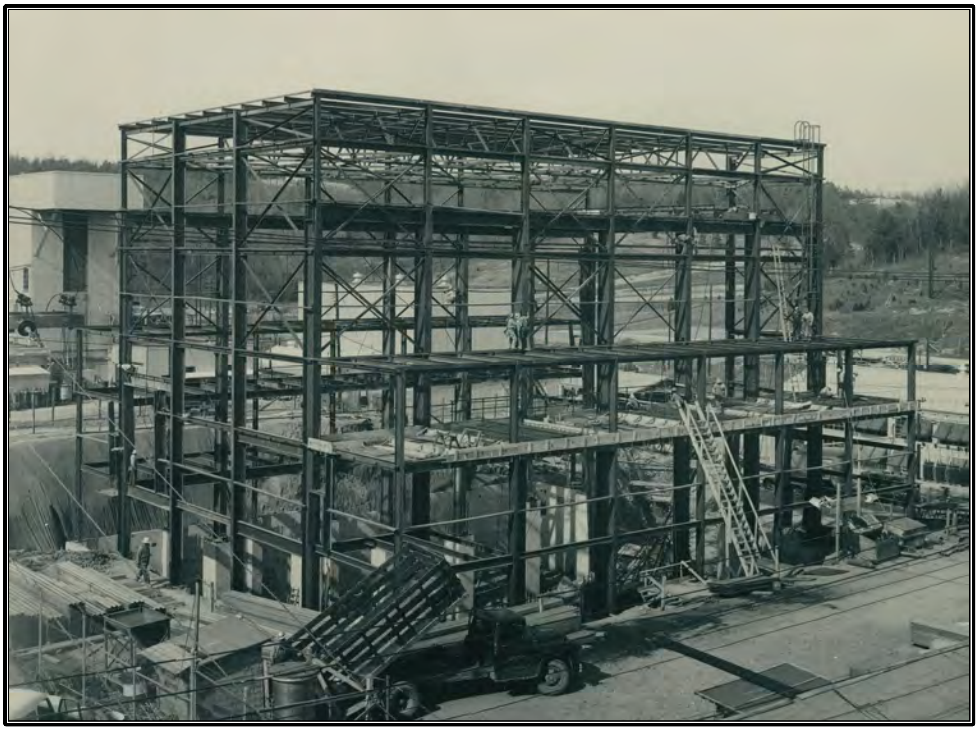


Figure 16. Archival photograph of the construction of Building 3042 showing the erection of the steel frame, March 1, 1956 (ORNL Photo 56-0164).

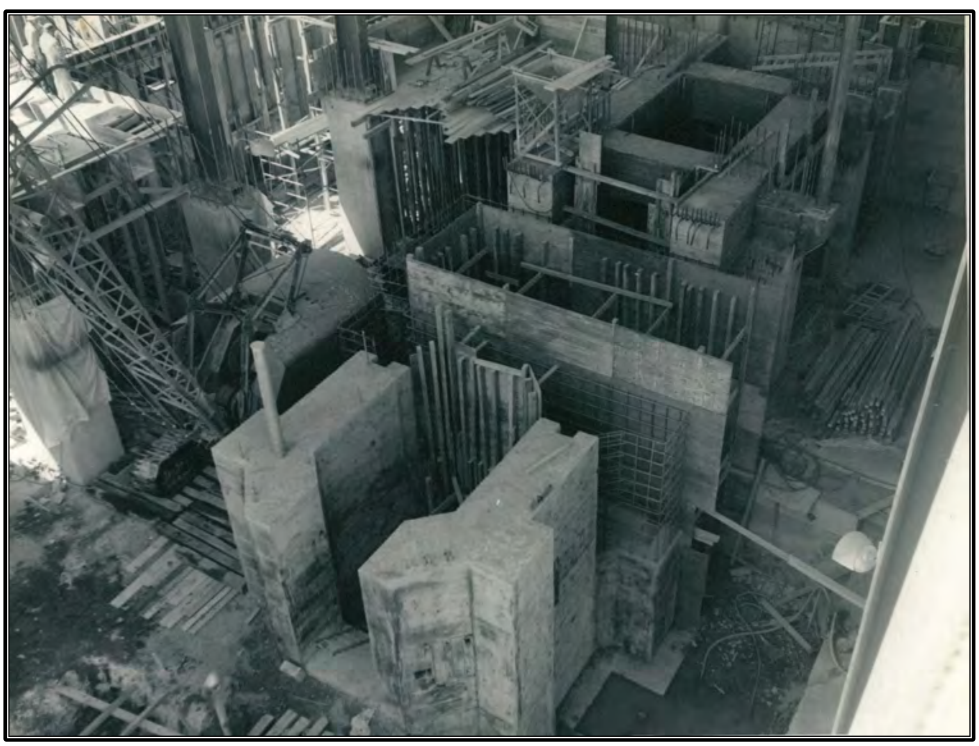


Figure 17. Archival photograph of the construction of Building 3042 showing the foundation for the reactor, May 17, 1956 (ORNL Photo 56-0492).

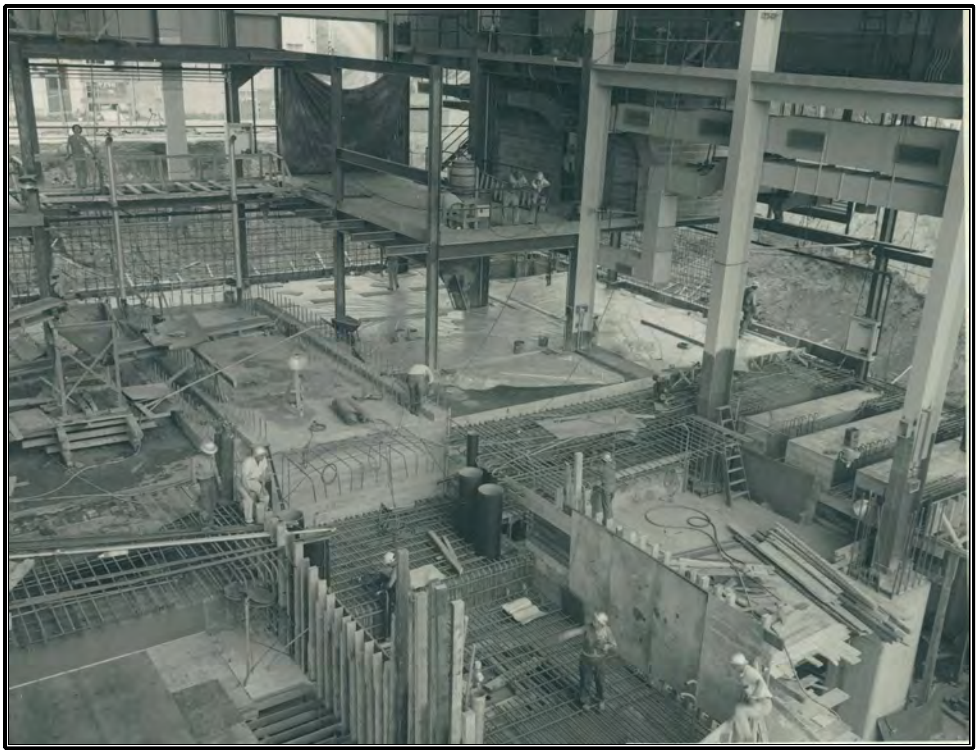


Figure 18. Archival photograph of the construction of Building 3042 showing the interior looking toward the west wall, July 18, 1956 (ORNL Photo 56-0715).

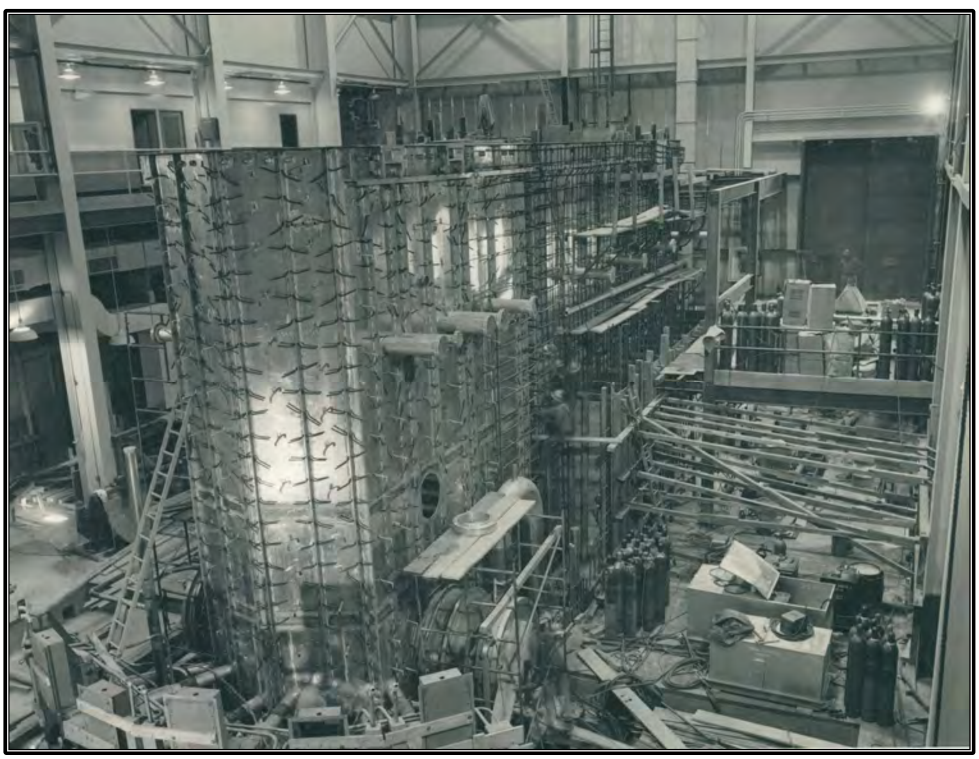


Figure 19. Archival photograph of the construction of Building 3042 showing the ORR structure, January 17, 1957 (ORNL Photo 57-0023).

Figure 20. Archival photograph of the construction of Building 3042 showing the ORR structure in the high bay, April 18, 1957; along the bottom of the structure are six beam holes for use in experiments (ORNL Photo 57-0510).

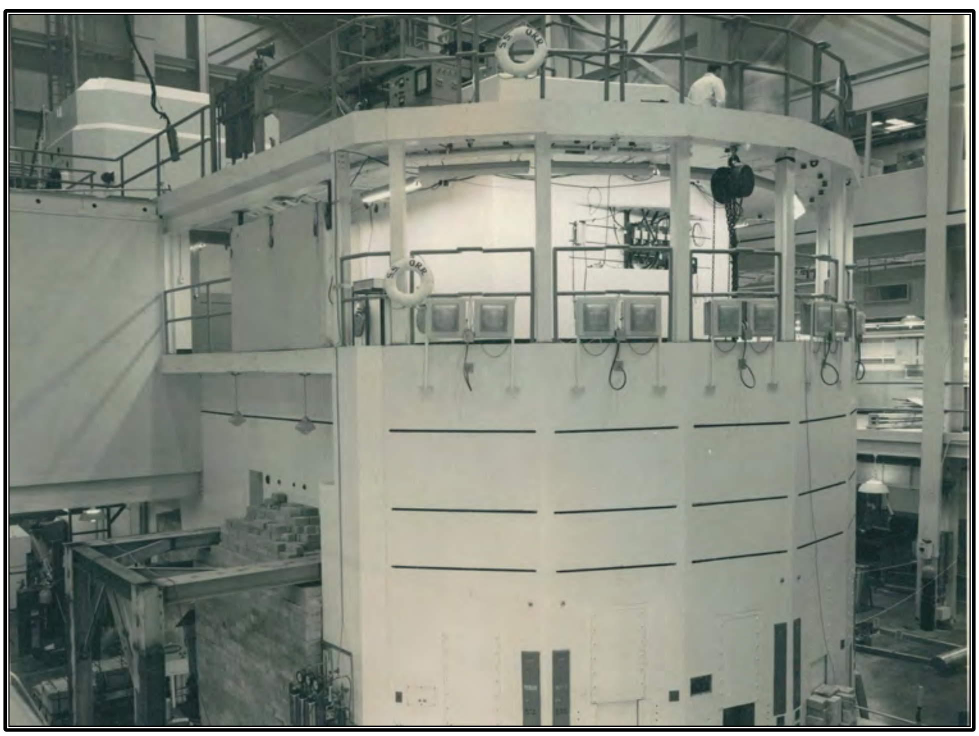


Figure 21. Archival photograph of the construction of Building 3042 showing the completed ORR, June 26, 1958 (ORNL Photo 58-0512).

The earliest architectural drawings available for Building 3042 date to 1954, showing the central high bay containing the reactor and two levels of balconies along the north and south walls (Figures 22 and 23) (ORNL 1954a). Flanking the high bay were two wings, each three stories tall including the basement. Beneath the first floor of the building the basement level held the concrete support structure for the reactor, a 6 ft by 6 ft pit beneath the reactor, a fan and filter room in the southeast corner, and an electric power distribution center on the south wall. The first floor was dominated by the lower level of the reactor, with a truck entry on the east side (Figure 24) (ORNL 1954b). The central portion of the second floor was devoted primarily to the reactor facility, with restrooms in the northwest corner, and a truck 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. At the third-floor level of the high bay was the top portion of the reactor. The third floors of the two wings were subdivided to provide a row of offices, a control room, and an equipment and instrument repair room (later an instrument shop) in the north wing, and a row of laboratories in the south wing. Originally the building was to encompass approximately 30,700 sq ft of floor space, with a gross building volume of 831,000 cubic ft (Cole and Gill 1957:35). The basement was to contain approximately 11,400 sq ft, the first floor 9,500 sq ft, the second floor 3,000 sq ft, and the third floor 6,800 sq ft (Cole and Gill 1957:34–35).

Numerous changes were made to the architectural plans for the elevations of Building 3042 between 1954 and 1955. These included the replacement of the roll-up doors in the service entries with double-leaf metal-clad wood doors, rearranging of the roof ventilators, the addition of roof access ladders on the north and south elevations, alterations to the fire escapes on the east elevation, additional louvered openings on all elevations, the removal of exterior stairs planned for the north and south elevations, and the addition of air intake stacks on the south elevation (ORNL 1954a, 1954b, 1954c, 1954d, 1954e, 1954f, 1954g, 1954h, 1954i; McPherson Company 1955a, 1955b, 1955c, 1955d, 1955e).

Although initially the building was not to include change rooms for personnel, with the assumption that employees would utilize the change rooms in nearby facilities, in the summer of 1957, partway through construction, architectural plans were altered to include a three-story extension on the north elevation to function as a change house, with service facilities at the first floor level (Figures 25 and 26) (ORNL Engineering Department 1957; ORNL n.d.a). Due to the hillside, the first floor of the Change House was constructed below-grade and referred to as the Service Basement (Figures 27–29). Access to the Service Basement in the Change House Addition was provided by a set of stairs set onto the hillside. The retaining wall-enclosed well also provided access to an entry on the north elevation of the original building (ORNL n.d.b, n.d.c).

In the fall of 1958, a small concrete-block structure was built on the north elevation of the change-house addition at the second-floor level, which functioned as Bottled Gas Storage, pertaining to such experiments as the Beryllium Irradiation Study and MSRE research (see Figure 27) (ORNL Engineering Department 1958). Ultimately the interior of Building 3042 contained approximately 37,369 sq ft (UCOR 2016:4). While a few minor additions were made to the exterior of the building in the following years, the footprint of Building 3042 remained mostly unchanged after construction completed circa 1958.

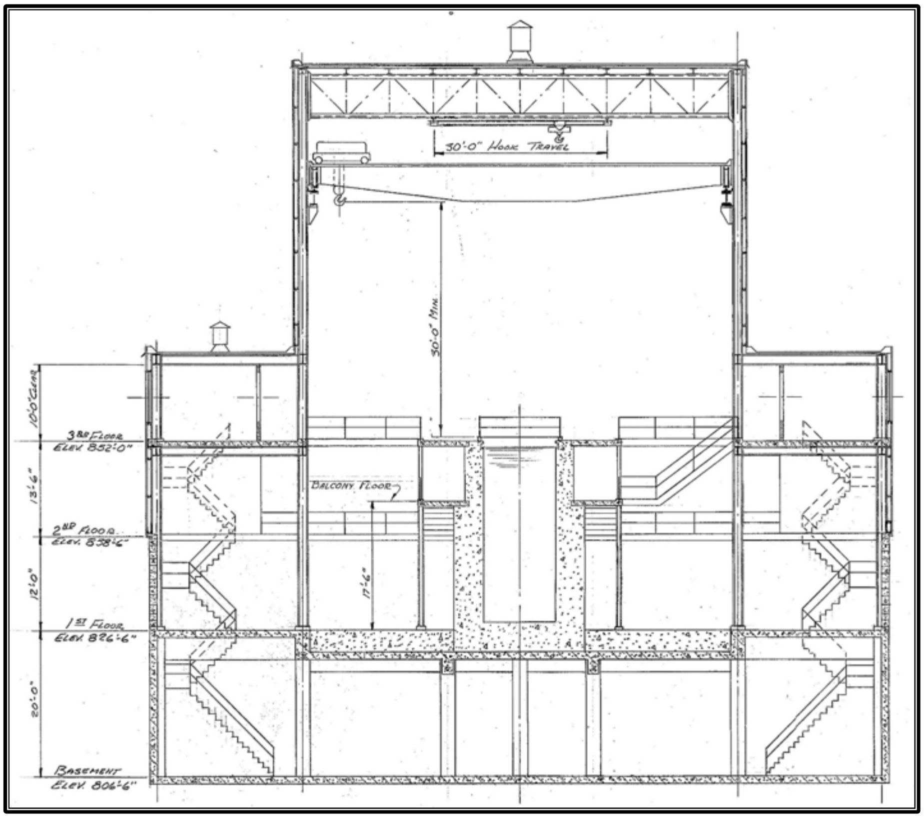


Figure 22. Portion of architectural drawing (D-18661) showing a transverse section through Building 3042, circa 1954 (ORNL 1954a).

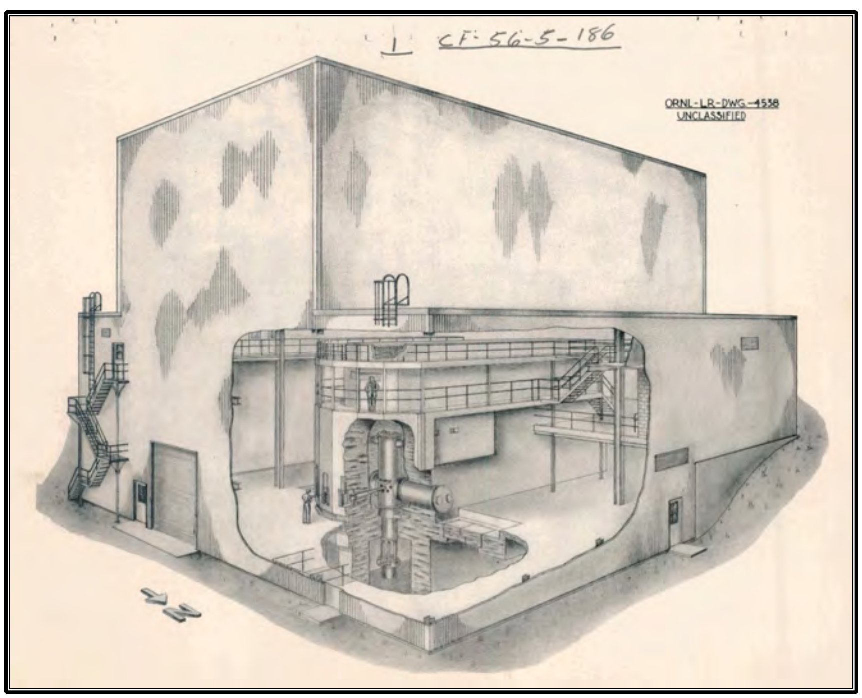


Figure 23. Three-dimensional, cutaway drawing (ORNL-LR-DWG-4538) of Building 3042 and the ORR, circa 1956, showing the multiple levels of both the building and of the reactor structure (Wright 1956:1).

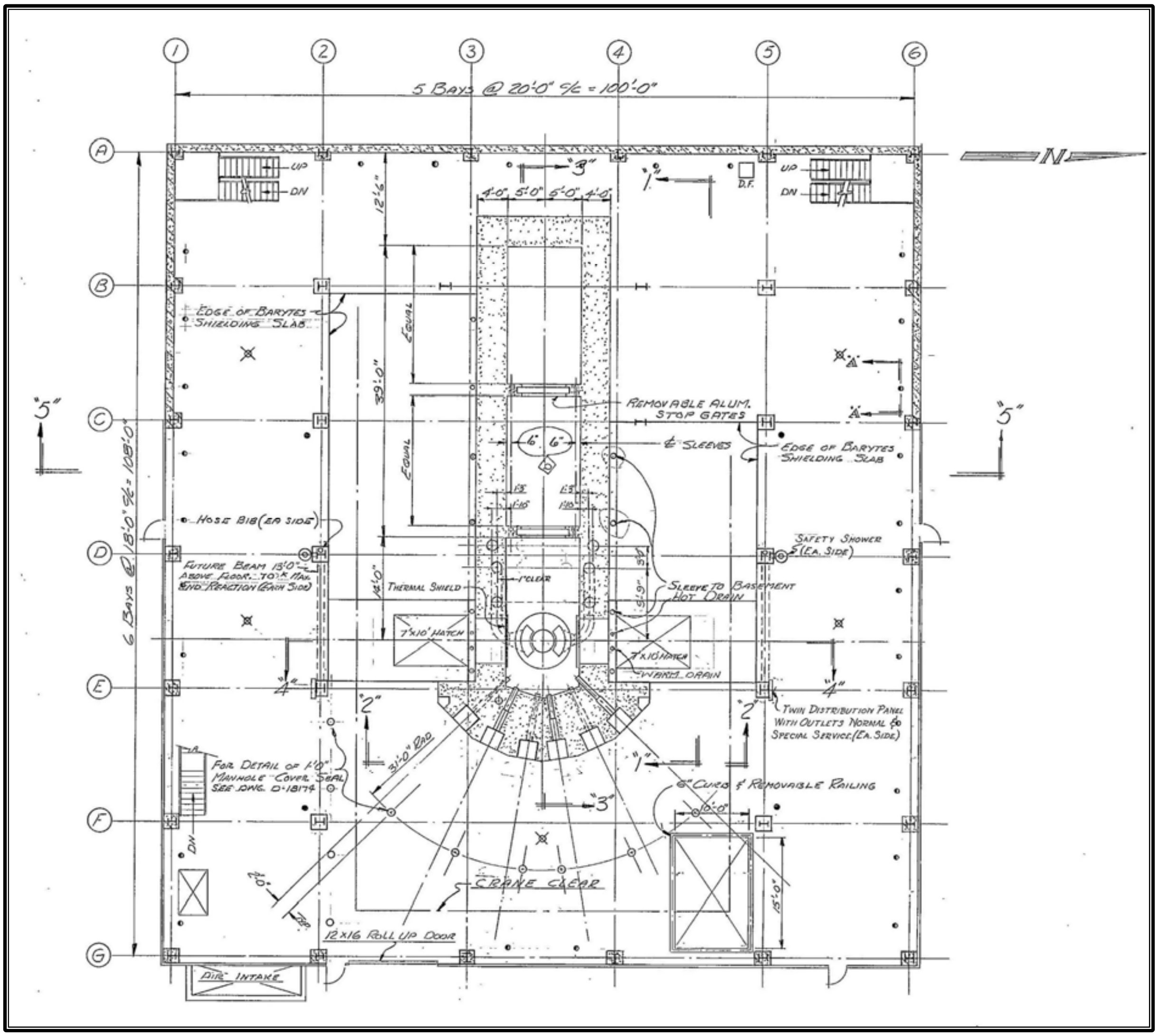


Figure 24. Portion of architectural drawing (D-18656) showing the first floor plan for Building 3042, circa 1954 (ORNL 1954b).

Figure 25. Archival photograph of change house extension on the north elevation of Building 3042, circa 1957 (ORNL Photo 42104).

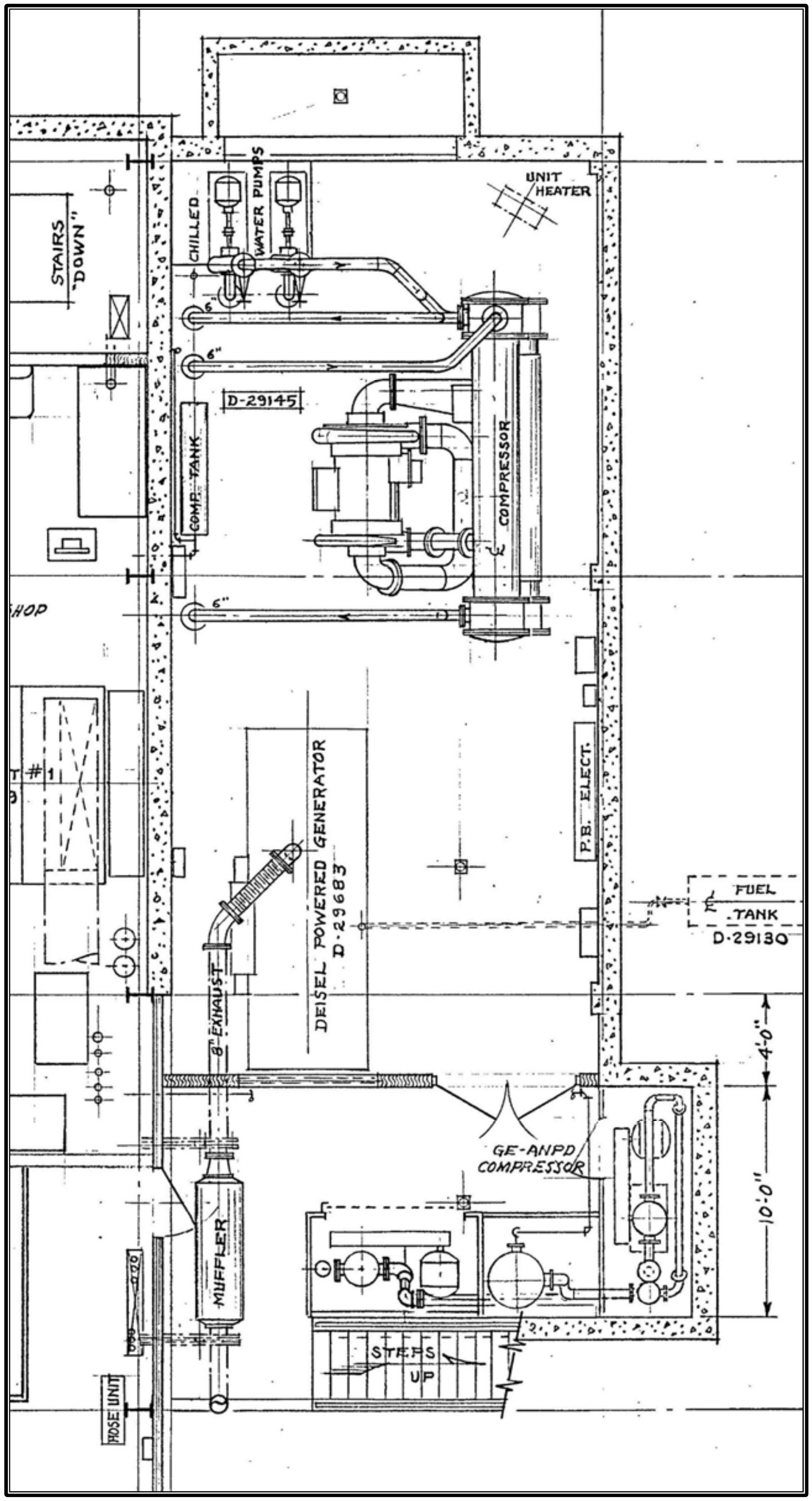


Figure 26. Portion of architectural drawing (E-31271) showing the below-grade first floor of the Change House addition, referred to as the Service Basement, circa 1968. The below-grade well contained by retaining walls, providing access to both the Service Basement via a double-leaf entry and the first floor of the main building via a single-leaf entry, is at bottom (ORNL 1968a).

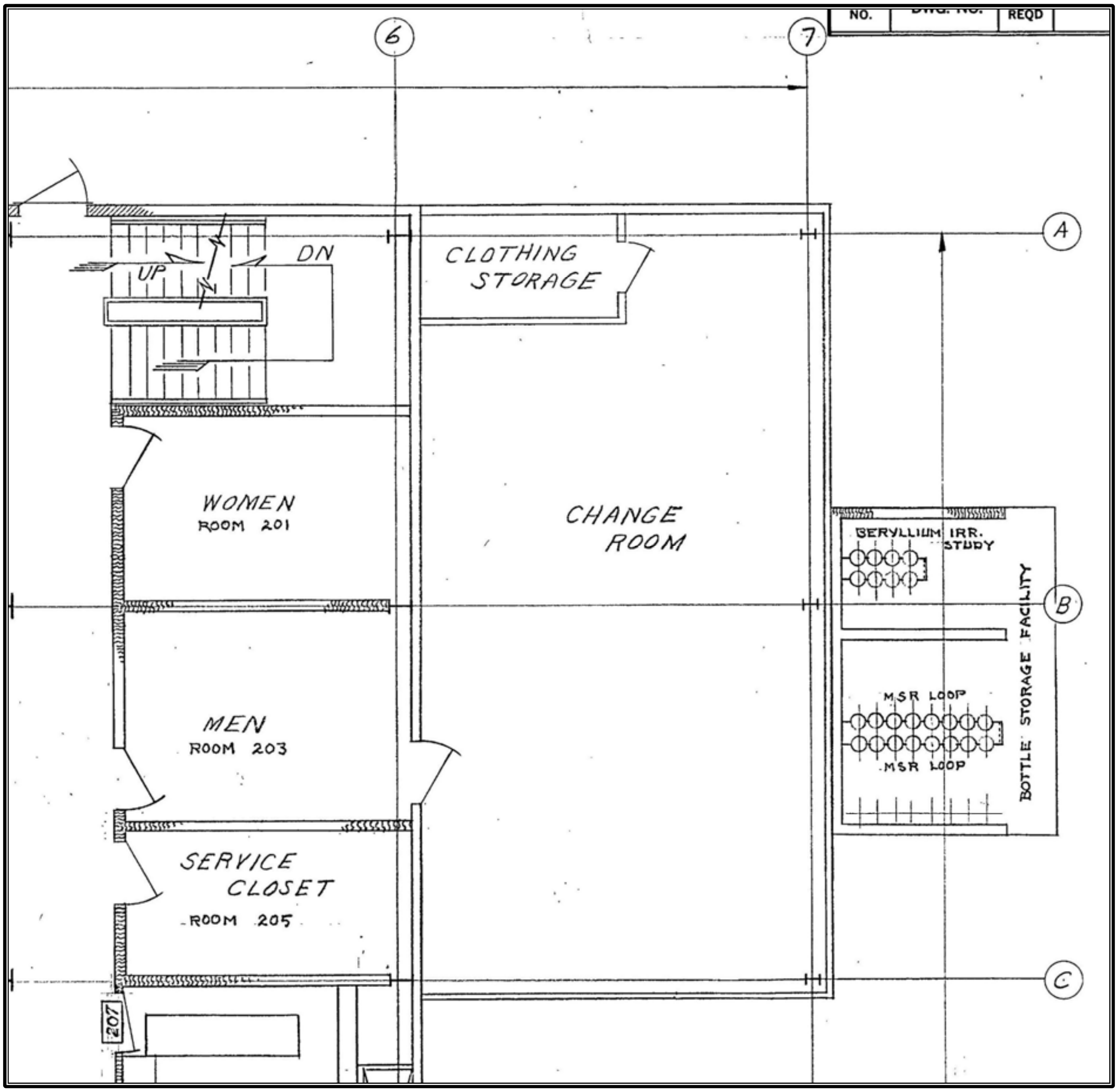


Figure 27. Portion of architectural drawing (E-31272) showing the second floor of the Change House addition on the north elevation of Building 3042, circa 1968 (ORNL 1968b).

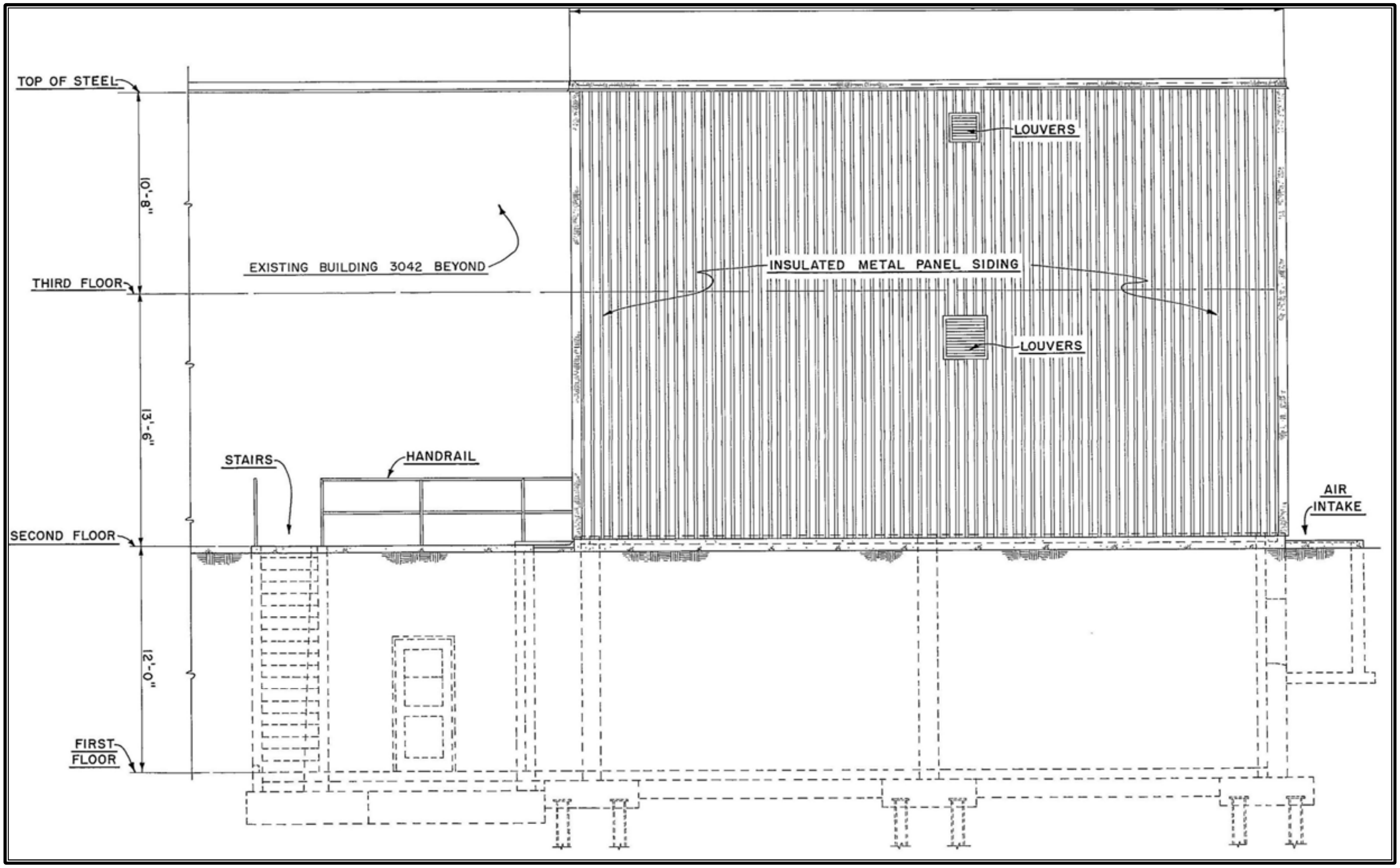


Figure 28. Portion of architectural drawing (C-28308) showing the north elevation of the Change House Addition, constructed on the north elevation of Building 3042 circa 1957, while the entire building was still under construction. The first floor of the Change House served as a Service Basement in the addition, but was contiguous with the first floor of the rest of the building (ORNL n.d.c).

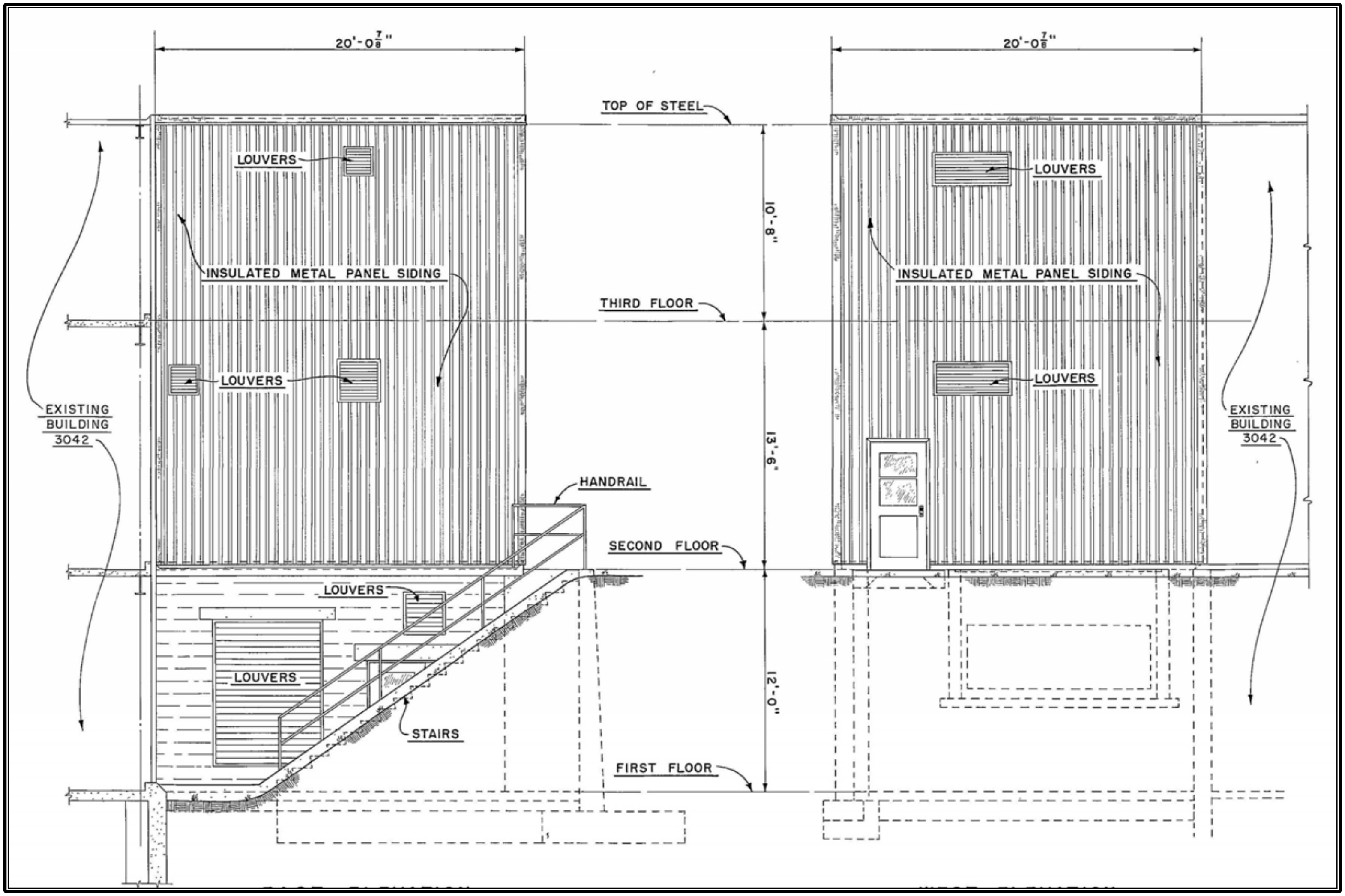


Figure 29. Portion of architectural drawing (C-28309) showing the east elevation (left) and west elevation (right) of the Change House Addition, constructed on the north elevation of Building 3042 circa 1957, while the entire building was still under construction. The below-grade first floor of the Change House, referred to as the Service Basement, and the access stairs are visible on the east elevation (left). The floor levels of the primary mass of Building 3042 are labeled at center (ORNL n.d.b).

A shed-roof addition was added to the south elevation of Building 3042 sometime before 1960 and appears on as-built drawings issued in 1963 and 1968 (Figures 30 and 31). Originally, the 1954 and 1955 plans for the south elevation of Building 3042 called for one single-leaf entry at the first-floor level. A double-leaf entry was added to the south elevation, east of the original single-leaf entry and sheltered by the shed-roof addition, at an unknown date prior to 1968, according to an as-built drawing issued in June of that year. This double-leaf entry became a single-leaf entry at an unknown date after 1981 (Figure 32) (McPherson Company1955b; ORNL 1963, 1968a). A second one-story, enclosed shed-roof addition was constructed on the south elevation at an unknown date between 1963 and 1968, as shown in an as-built drawing issued in 1968. This enclosed shed-roof addition extends south of Building 3042 along the west retaining wall (see Figure 31). Additionally, a vestibule was added to the first-floor, single-leaf entry on the east elevation. Single-leaf entries were also added along the fire escapes of each wing on the east elevation sometime between 1957 and 1963, providing access to the second floor (see Figures 7 and 8). Metal awnings were added above two of the west elevation pedestrian entries at an unknown date after 1960 (see Figures 11, 25, and 30) (ORNL 1963, 1968a).

Preliminary plans were drafted between 1981 and 1982 to construct an addition to the south elevation to house a Neutron Antineutron Oscillation Experiment (Union Carbide Corporation 1981a, 1981b). This addition is not presently extant; therefore, it is unlikely the construction ever occurred.

Associated with Building 3042 were several important support structures. Constructed simultaneously to the ORR and located northeast of Building 3042 was a collection of structures related primarily to the cooling systems for the pool water and the reactor core, including a circa 1958 heat exchanger (Building 3087), two circa 1958 cooling towers (Buildings 3086 and 3089), a circa 1959 pump house (Building 3085), an underground decay tank, and storage tanks. There were also two 20,000-gallon retention ponds to be used in the event a large quantity of contaminated water needed to be disposed of. Two underground cooling lines connected Building 3042 to these structures, one leading to the cooling tower and the other to the pumping station and heat exchangers (Figure 33) (Cole and Gill 1957:13–14, 54; Carver and Slater 1994:157). Archival photographs show the first iterations of a cooling tower, the pump house, and heat exchanger, when the ORR operated at 20 Mw (Figures 34 and 35).

As ORR operations proceeded, functional issues quickly became apparent in the air-cooled heat exchangers (Tabor and Costner 1962:45). In addition, limitations in the cooling capacity of the exchangers during summer months meant that some experiments could not be adequately performed. Subsequently, several modifications were made to the cooling system to improve its operations. In the fall of 1959, it was proposed to increase the reactor's power level to 30 Mw in order to better meet ORNL research needs, which meant more substantial alterations to the cooling system would be necessary, including additional heat exchangers of stainless steel (Building 3102), situated in an earthen pit, and a new two-cell, crossflow cooling tower (Building 3103), completed in the summer of 1960 (Figures 36 and 37) (Hamrick and Swanks 1968:2; Tabor and Costner 1962:50, 56).

Other ancillary facilities were related to venting the building. The ORR building was specifically designed to prevent the release of radioactive gases into the atmosphere using the concept of "dynamic containment," which meant the building was partially airtight, with a continually operating controlled exhaust system that pulled air into the building through leakage points and then out through a 250 ft brick stack. This succeeded in maintaining a slight vacuum in the building (Hamrick and Swanks 1968:8). South of the building, in the early years of the ORR's operations, the ventilation ductwork leading from the basement was intercepted by a facility containing a caustic scrubber before entering the stack (Figure 38) (Tabor and Costner 1962:72). Normally, the scrubber was deactivated, but in the event of a radiation emergency, the ORR building was sealed by closing such openings as vents and exterior doors, and the scrubber was called into action to decontaminate the air before it entered the stack (Tabor and Costner 1962:71). Later a charcoal filter-type decontamination unit (Building 3126) replaced the caustic scrubber. Other buildings historically associated with the ORR in Building 3042 were Building 3098, a Filter House servicing both the BSR and ORR; Building 3109, a Process Off-Gas Filter facility; and Building 3139, a Cell Ventilation Filter facility (Carver and Slater 1994:157). This recordation only addresses Building 3042.

The ORR was shut down in 1987 and all reactor fuel, shim rods, and beryllium were removed, and the hot cells were cleared of equipment by the end of the decade. As of 1994, offices in the building were still occupied by the RRD (Carver and Slater 1994:231; UCOR 2015:10). 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 (Figure 39) (UCOR 2015, 2016).

The exterior and interior architectural components of Building 3042 are described in greater detail below. The exterior is addressed by elevation (north, west, south, and east). The interior is addressed generally by floor, with a separate section pertaining to the multi-story reactor structure, which is nearly free-standing within the high-bay portion of the building.

Figure 30. Archival photograph showing the west and south elevations of Building 3042, circa 1960. At bottom right, the shed-roof addition constructed at an unknown date protrudes from the south elevation (ORNL Photo 51411).

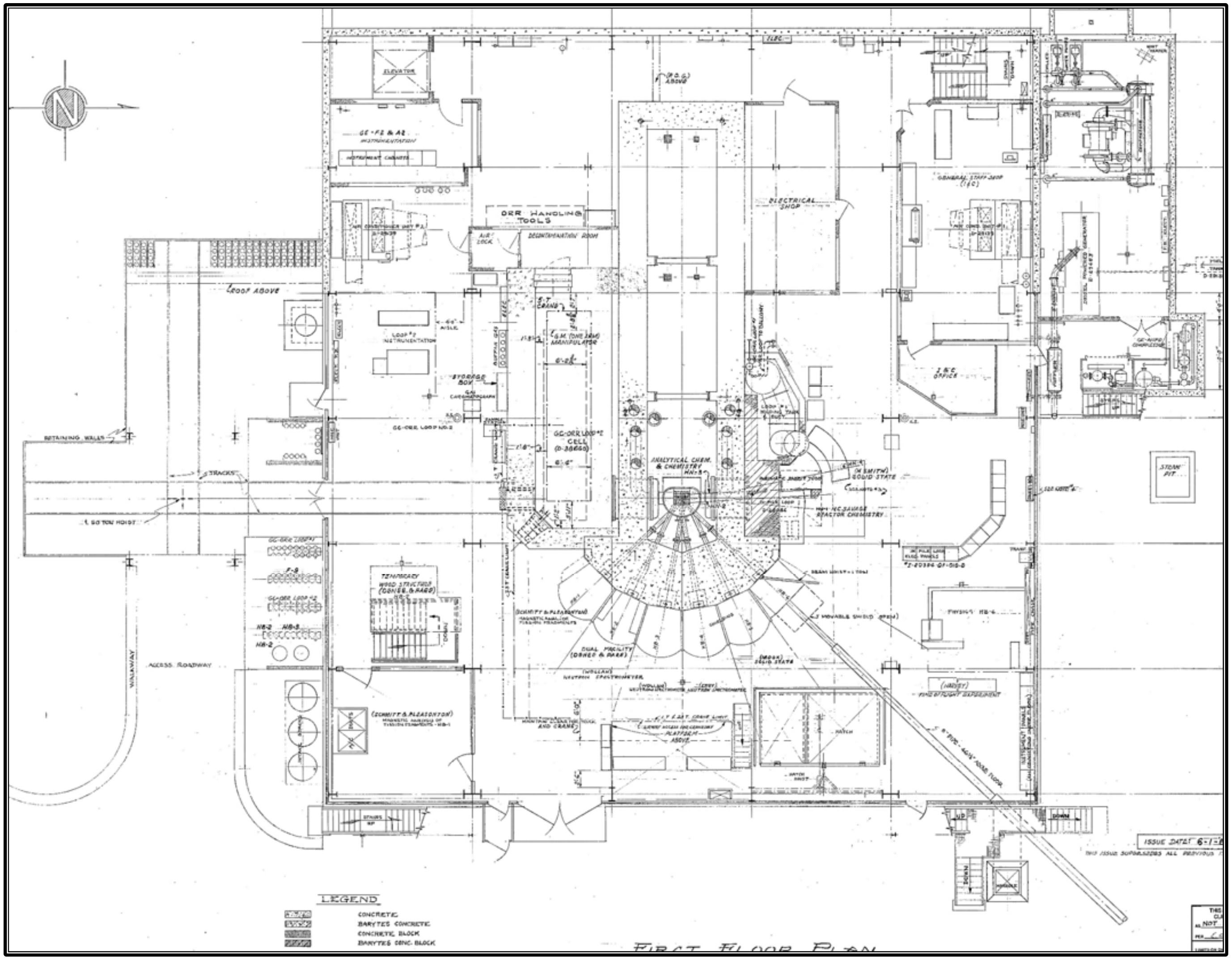


Figure 31. Architectural drawing (E-31271) showing the first floor of Building 3042, as-built, issued in 1968. At center left, the shed-roof addition to the south elevation shelters equipment as well as the double-leaf entry added at an unknown date. At top left, the second shed-roof addition to the south elevation protrudes south of the building along the retaining wall (ORNL 1968a).

Figure 32. Archival photograph showing the south elevation of Building 3042, circa 1981. An employee stands with a large piece of equipment placed in front of the double-leaf entry added to the south elevation at an unknown date between 1955 and 1968 (ORNL Photo 2652-81).

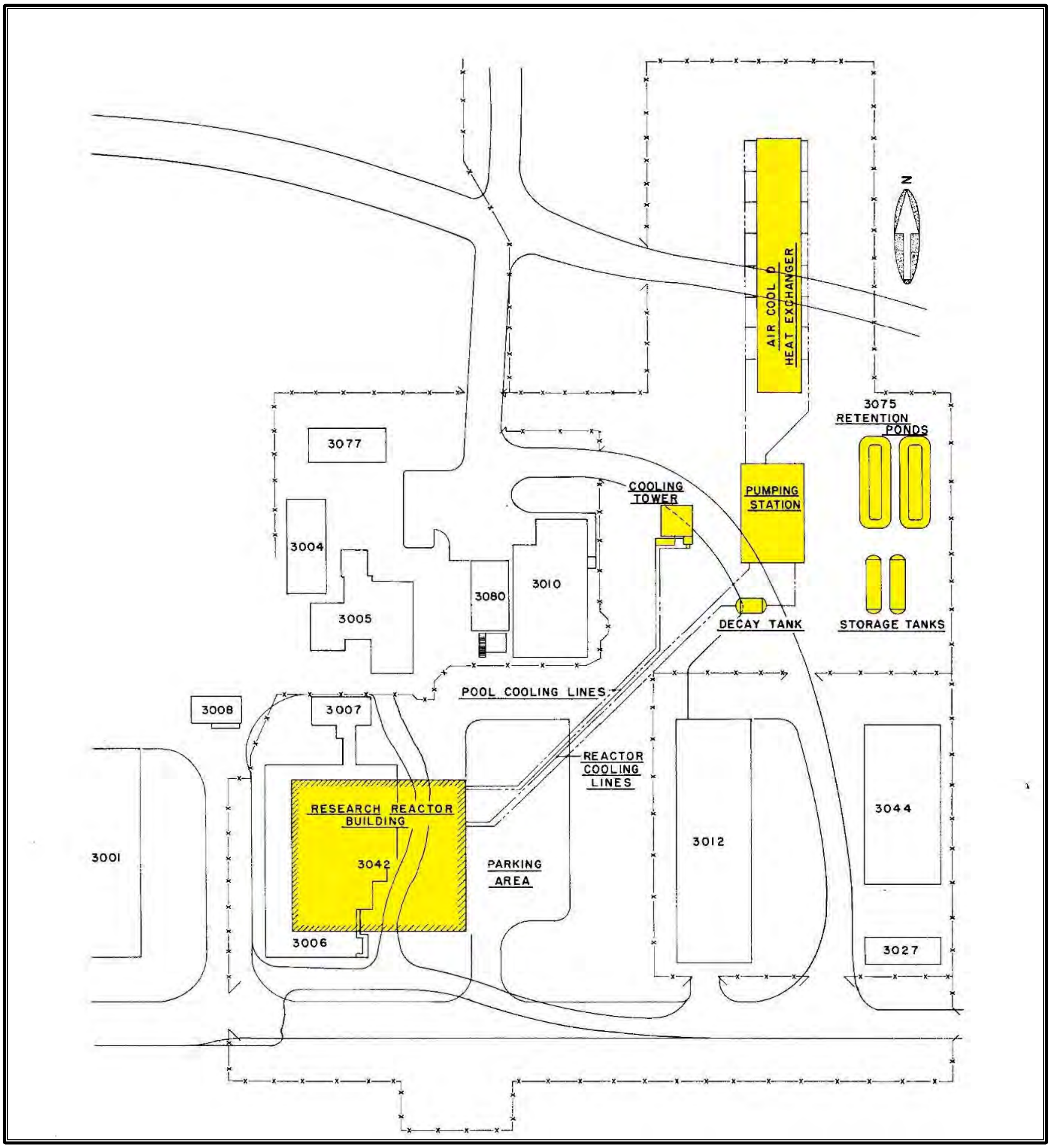


Figure 33. Plot plan, Drawing C-11389, showing the locations of Building 3042 and its ancillary structures, circa 1956 (highlights added) (Wright 1956:3).

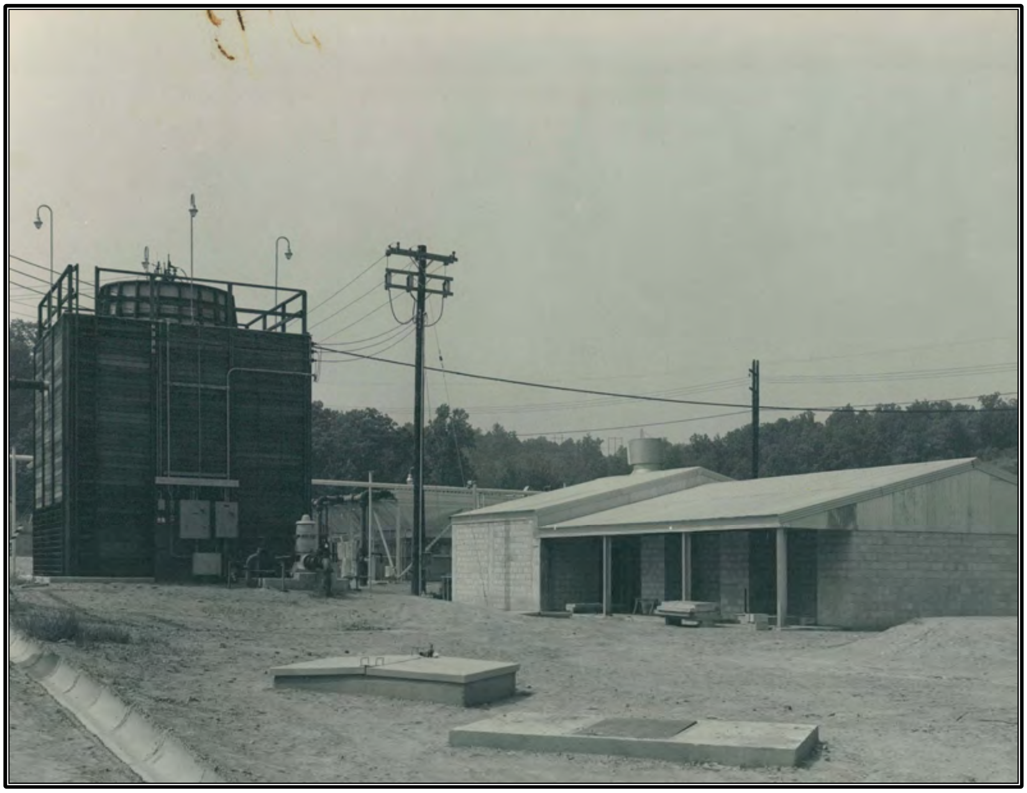


Figure 34. Archival photograph of a cooling tower (left), pump house (right), and heat exchanger (background) built for the ORR when it operated at 20 Mw, July 22, 1957 (ORNL Photo 57-1078).

Figure 35. Archival photograph of heat exchanger for the ORR, July 17, 1956 (ORNL Photo 56-0718).

Figure 36. Archival photograph of a new cooling tower and pump house for the ORR, which would accommodate an increase in the reactor's power level from 20 Mw to 30 Mw, July 13, 1960 (ORNL Photo 50640).

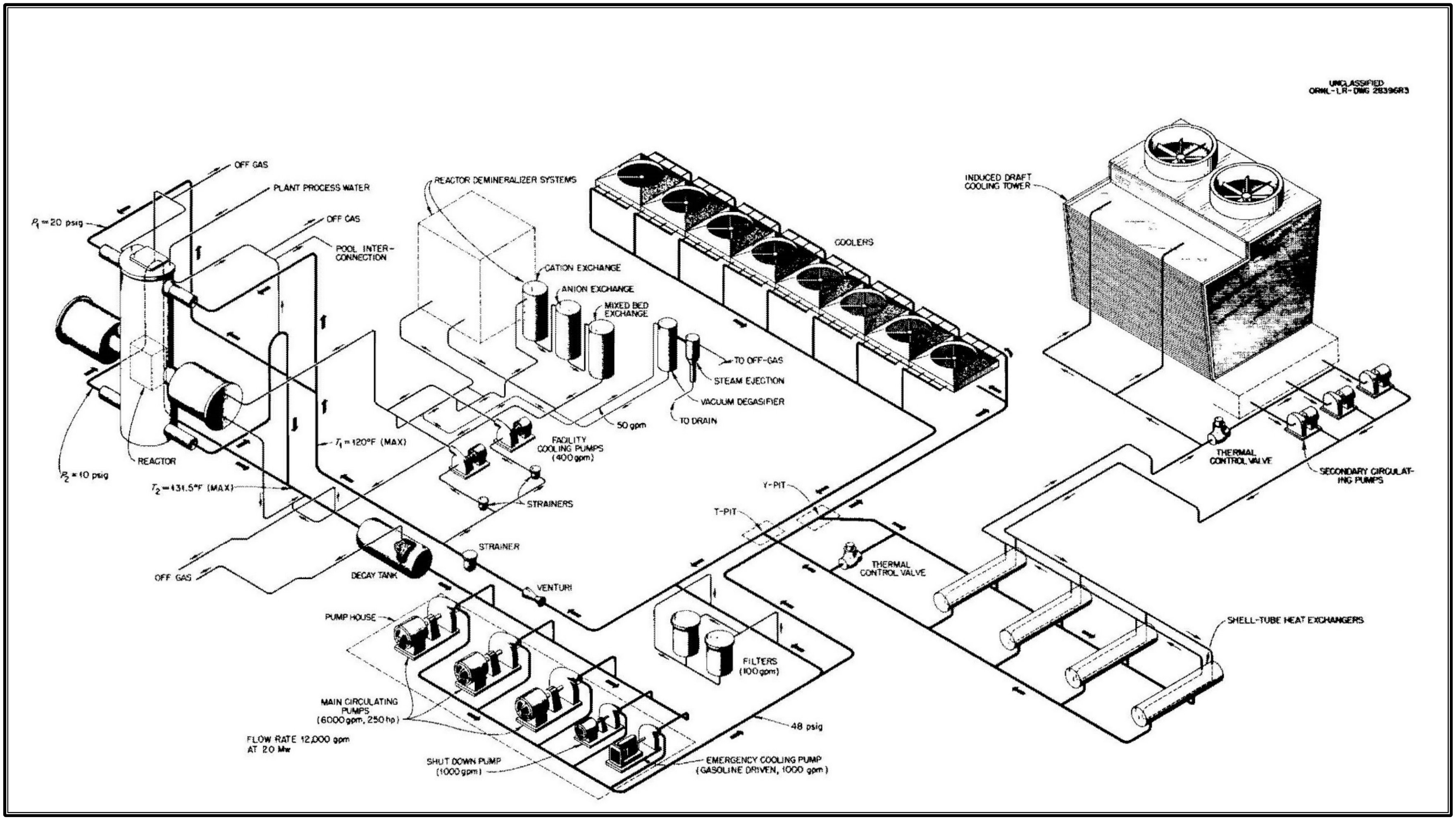


Figure 37. Drawing (ORNL-LR-DWG 28396R3) showing a diagram of the reactor cooling system for 30 Mw operation, circa 1962. The reactor structure appears at left and the circa 1960 cooling tower is at right (Tabor and Costner 1962:51).

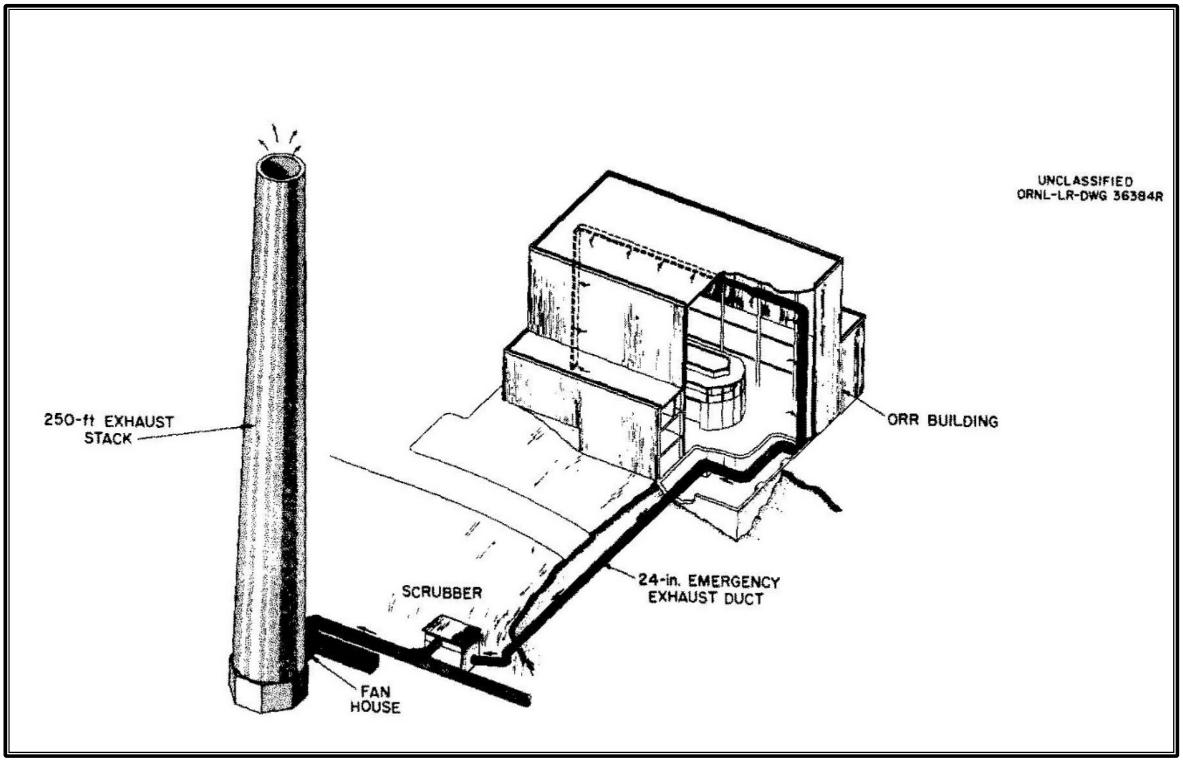


Figure 38. Illustration of the ORR's emergency ventilation system, which included a caustic scrubber facility, located south of the building (Tabor and Costner 1962:72).

Figure 39. Circa 2015 photograph showing the reactor pool capped with concrete shielding panels, facing southwest (UCOR 2016:22).

Exterior of Building 3042

Building 3042 is comprised of three rectangular box-shaped sections with varying roof heights that together cover an area approximately 111 ft long by approximately 103 ft wide (Hamrick and Swanks 1968:38). Set on a poured-concrete foundation, the building is nestled into a hillside and thus the first-floor level is below grade; beneath the first floor is a full basement level. 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 approximately 59 ft above grade on the west elevation and 71 ft on the east elevation (Hamrick and Swanks 1968:38). The north and south "service wings" of the building, also called low bays, are each three stories in height, measuring 20 ft wide and approximately 36 ft from the first floor to the roof beams (Cole and Gill 1957:34; Wright 1956:2). The basement extends 20 ft below the first floor.

The north elevation features a partial-width three-story addition, including a below-grade basement level contiguous with the first level of the main building, constructed circa 1957 (see Figures 25–29). Attached to the north elevation of the Change House addition at grade, on the second-floor level, is a small concrete-block addition divided into two open stalls that functioned as a bottled-gas storage facility. The south elevation features a one-story, concrete-block, shed-roof addition that is open along the south side, and a one-story shed-roof addition clad in metal panels.

The primary mass of the building is composed of a structural steel frame clad in corrugated, insulated metal panels. Below grade the walls are of reinforced concrete (Cole and Gill 1957:34). The building is windowless in order to eliminate glare on the surface of the reactor pool, and to facilitate making the building airtight in the event of an emergency (Wright 1956:2). Pedestrian entries are single- or double-leaf and filled by metal doors with either small single lights or two lights. Some pedestrian entries are sheltered by shed-roof metal awnings. On the east and west elevations of the building are service/truck entries that are double-leaf, approximately 12 ft wide by 16 ft high, and filled by pairs of large metal clad wood doors; due to the change in grade, the east elevation service entry accesses the first floor and the west elevation service entry accesses the second floor (Tabor and Costner 1962:82). All sections of the building are sheltered beneath a flat roof of steel decking overlaid with metal panels sealed with a layer of felt and bitumen, and a top layer of insulation (McPherson Company 1955f:15-1–15-2; UCOR 2016:4). Projecting from the roof of the high bay are six exhaust fans (McPherson Company 1955f:25-1).

Architectural drawings of the elevations of Building 3042 dated later than 1955 showing the entire building included the circa 1957 Change House addition were not available for this recordation.

East Elevation

The east elevation of Building 3042 showcases the varying roof heights, with a high central portion flanked by north and south wings (Figure 40) (McPherson Company 1955a). The east elevation of the high-bay portion is pierced by a service entry at the first-floor level, filled by a pair of large hinged metal-clad wood doors. Louvered openings pierce the high-bay near the roof line (Figures 41 and 42). To the left of the service entry is a small vestibule pierced by a single-light metal door that leads to a second door accessing the building's interior (Figure 43). The east elevation of the north wing is pierced by three single-leaf entries, located at the first-, second-, and third-floor levels, accessed by an exterior metal fire escape (Figure 44). The east elevation of the south wing has a similar arrangement, but without an entry at the first floor (Figure 45). The east elevations of the north and south wings support roof access ladders featuring a round safety cage.

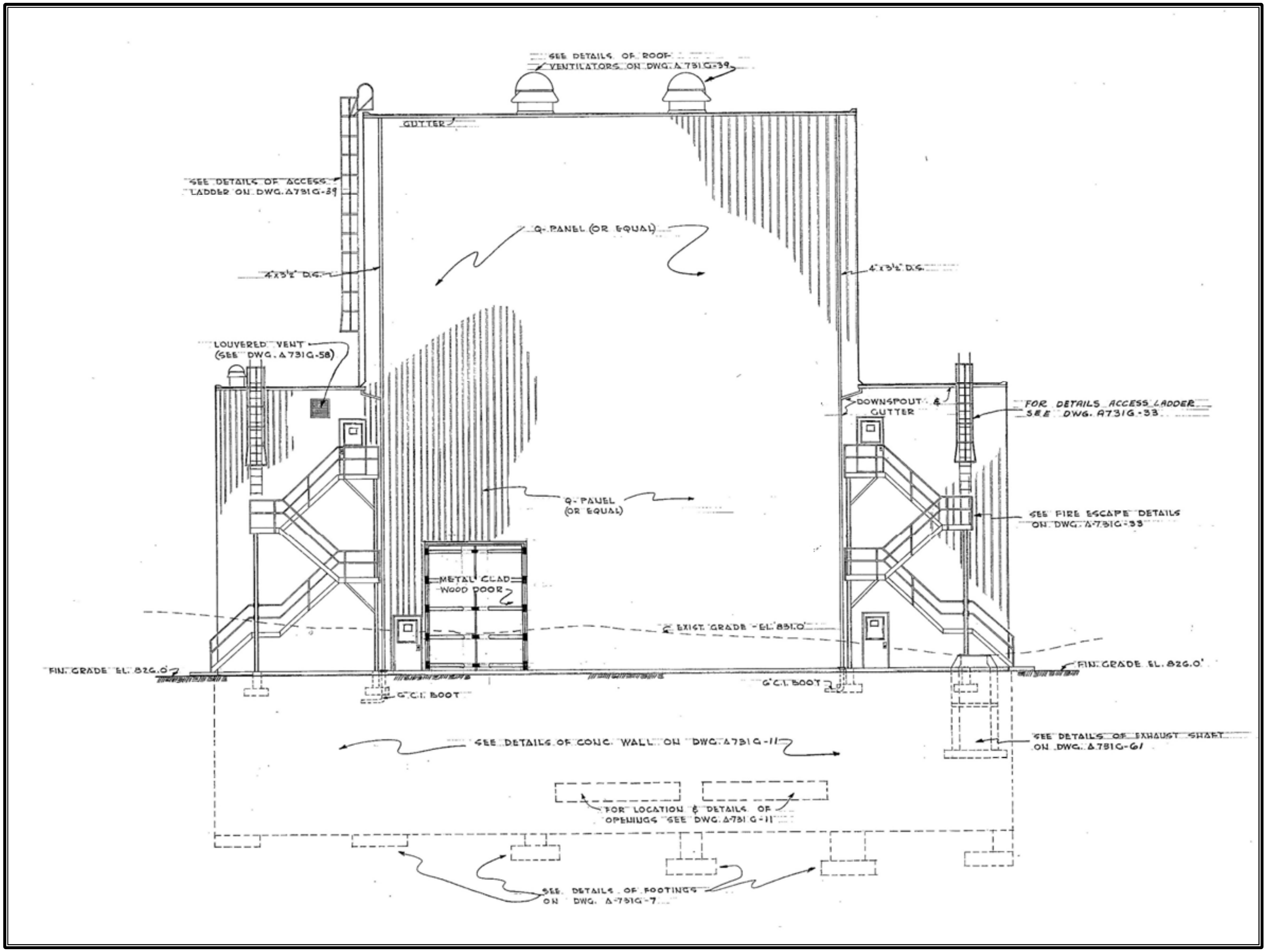


Figure 40. Portion of architectural drawing (D-22143) showing the east elevation of Building 3042, circa 1955 (McPherson Company 1955a).

Figure 41. Current photograph of east elevation of Building 3042, facing southwest.

Figure 42. Current photograph of service entry on the east elevation of Building 3042, facing south.

Figure 43. Current photograph of vestibule south of the service entry on the east elevation of Building 3042, facing west.

Figure 44. Current photograph of east elevation of north wing of Building 3042, facing west.

Figure 45. Current photograph of east elevation of south wing of Building 3042, facing west.

South Elevation

The south elevation of Building 3042 includes the south elevation of the south wing as well as the south elevation of the high-bay. The south elevation of the south wing features a one-story, shed-roof, concrete-block addition that is partitioned and open along the south side. A metal pole provides support for the shed roof and a gutter travels along the roofline. Beneath the shelter of the addition the building is pierced by one single-leaf entry at the first-floor level filled by a metal door with a single small light (Figures 46 and 47) (McPherson Company 1955b). Attached to the walls of the addition are racks for storing metal tanks as well as other equipment, dials, and gauges. To the east of the addition is a row of three vertical steel stacks, approximately 20 ft tall, attached to the southeast corner of the building, which functioned as fresh air intake (Figure 48) (McPherson Company 1955f:25-7). To the west of the addition is a former entry, the original single-leaf entry, covered by a metal panel. A single vertical steel stack is attached to the south elevation west of the infilled entry. Multiple louvered openings pierce the elevation near this stack. Attached to the west end of the south elevation is a one-story, shed-roof addition clad in corrugated metal panels (Figure 49). Piercing the east elevation of the addition is an entry filled by a metal-panel door on a metal track. Adjacent to the south elevation of the building is a steel gantry supporting an overhead crane (Figure 50). The south elevation of the high-bay supports a roof access ladder featuring a round safety cage.

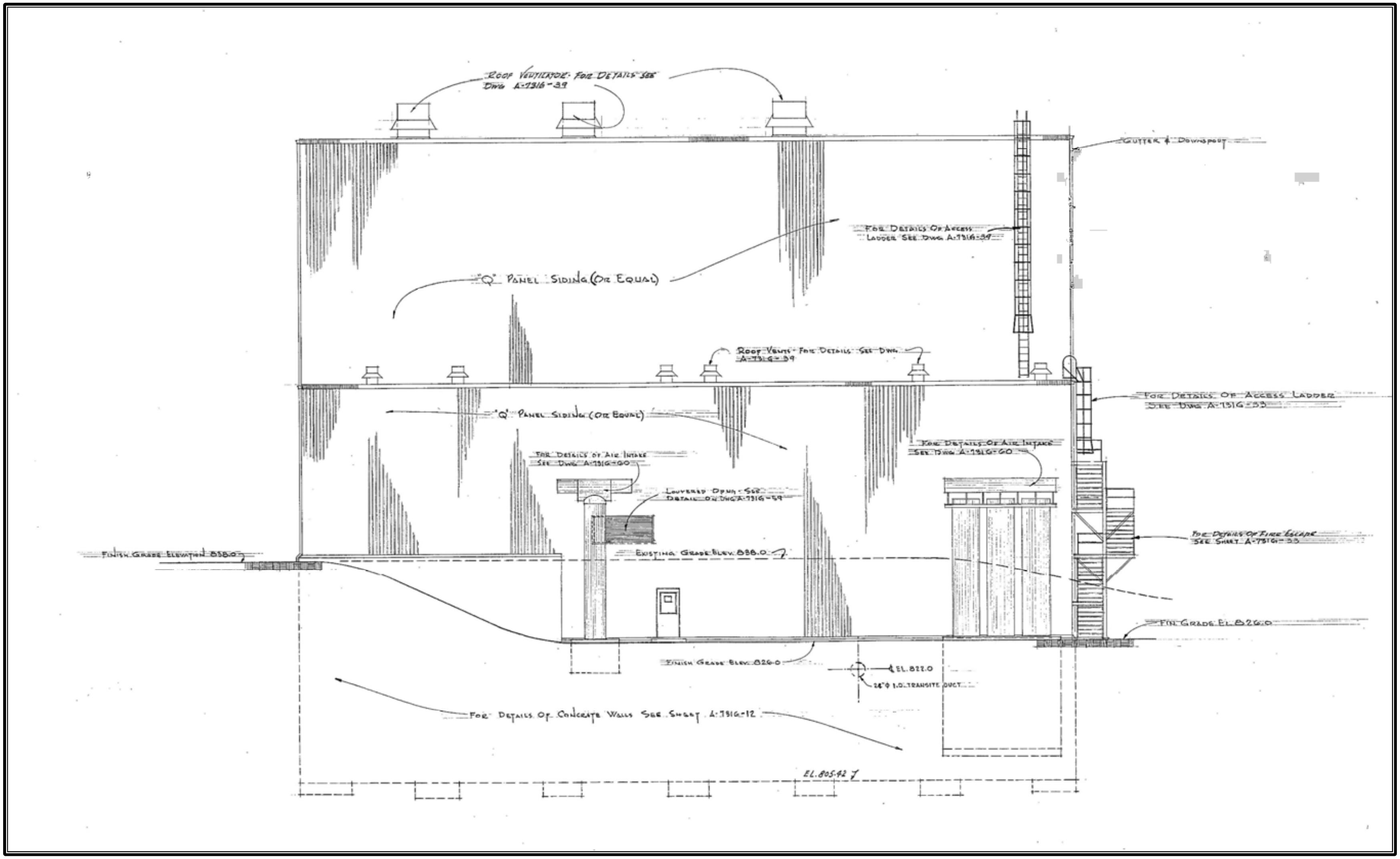


Figure 46. Portion of architectural drawing (D-22142) showing the south elevation of Building 3042, circa 1955 (McPherson Company 1955b).

Figure 47. Current photograph of south elevation of Building 3042 showing concrete-block addition, facing northwest.

Figure 48. Current photograph of south elevation of Building 3042 showing row of tanks at southeast corner, facing northwest.

Figure 49. Current photograph of south elevation of Building 3042 showing the metal-panel addition, facing north.

Figure 50. Current photograph showing gantry and crane adjacent to the south elevation of Building 3042, facing north. The south elevation of the high-bay appears at top.

West Elevation

The west elevation of Building 3042 presents as a simple plane pierced by four entries (Figures 51–53) (McPherson Company 1955c). The first-floor level of the building is below grade and not apparent in the west view. Circa 1957 the Change House addition was added to the north elevation of the building, which made the north and south wings asymmetrical on the west elevation. The central, high-bay portion of the west elevation is pierced by its original service entry, filled by a pair of large metal doors (Figure 54). The high-bay portion of the west elevation supports electrical conduit, fuse boxes, a loudspeaker, and other equipment. The west elevations of the north and south wings are each pierced by single-leaf entries filled by single-light metal doors, sheltered by shed-roof awnings suspended from metal rods. Another single-leaf entry pierces the northwest corner of the Change House addition to the north wing. Two louvered openings also pierce the Change House addition to the north wing.

North Elevation

Originally, plans for the north elevation of Building 3042 featured a single pedestrian entry below grade, accessed by a set of stairs leading down from the west (Figure 55) (McPherson Company 1955d). Circa 1957, plans for the north elevation were altered by construction of the Change House addition at the northwest corner that extends below grade; the upper portion of the Change House addition is clad in metal panels and the lower portion has concrete-block walls (Figures 56–58). Attached to the north elevation of the second floor of the Change House addition, at grade, is a one-story shed-roof addition with concrete-block walls, enclosed by metal-mesh gates on the north side. The north elevation of the Change House addition contains electrical conduit and supports a vertical metal pipe. The north elevation of the north wing, to the east of the Change House addition, is pierced by louvered openings and supports a vertical metal pipe. The first-floor level of the north elevation is below grade, accessed by a set of concrete steps leading to a well of formed-concrete retaining walls. Opening into the well from the first-floor level of the building is a single-leaf entry piercing the north elevation of the north wing. The north elevation of the north wing supports electrical conduit and a large metal muffler. A double-leaf entry pierces the concrete-block wall of the first floor of the east elevation of the Change House addition. A large, six-panel louvered opening pierces the east elevation of the Change House addition south of the double-leaf entry; another louvered opening pierces the east elevation of the Change House addition above the double-leaf entry. The first-floor of the east elevation of the Change House addition supports electrical conduit and two vertical metal pipes featuring capped downspouts. The second- and third-floors of the east elevation of the Change House addition are pierced by louvered openings and support electrical conduit (Figures 59 and 60).

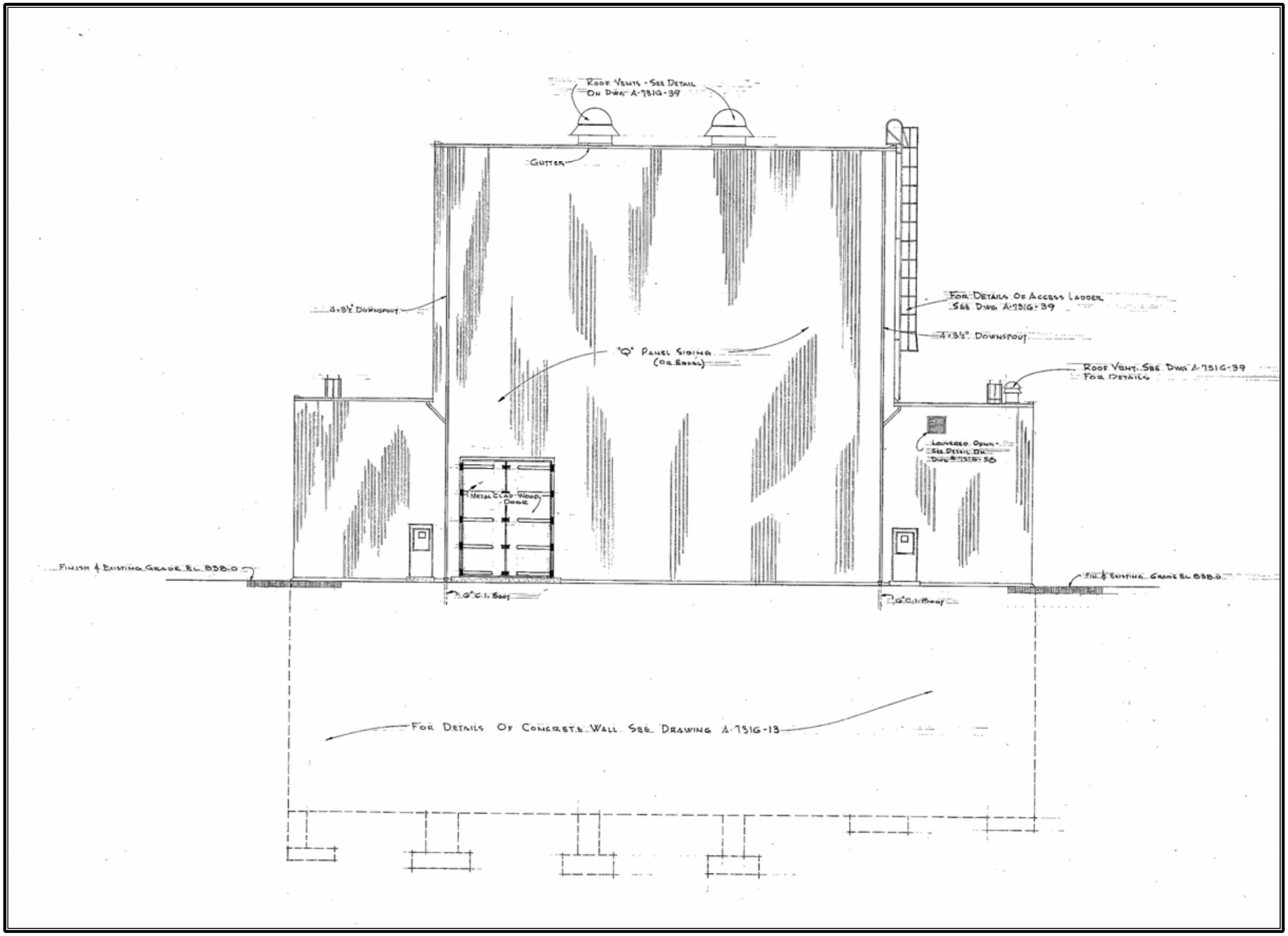


Figure 51. Portion of architectural drawing (D-22144) showing the west elevation of Building 3042, circa 1955 (McPherson Company 1955c).

Figure 52. Current photograph of west elevation of Building 3042, including the west elevation of the circa 1957 Change House addition at left, facing northeast.

Figure 53. Current photograph of west elevation of Building 3042, facing southeast.

Figure 54. Current photograph of service entry on the west elevation of Building 3042, facing east.

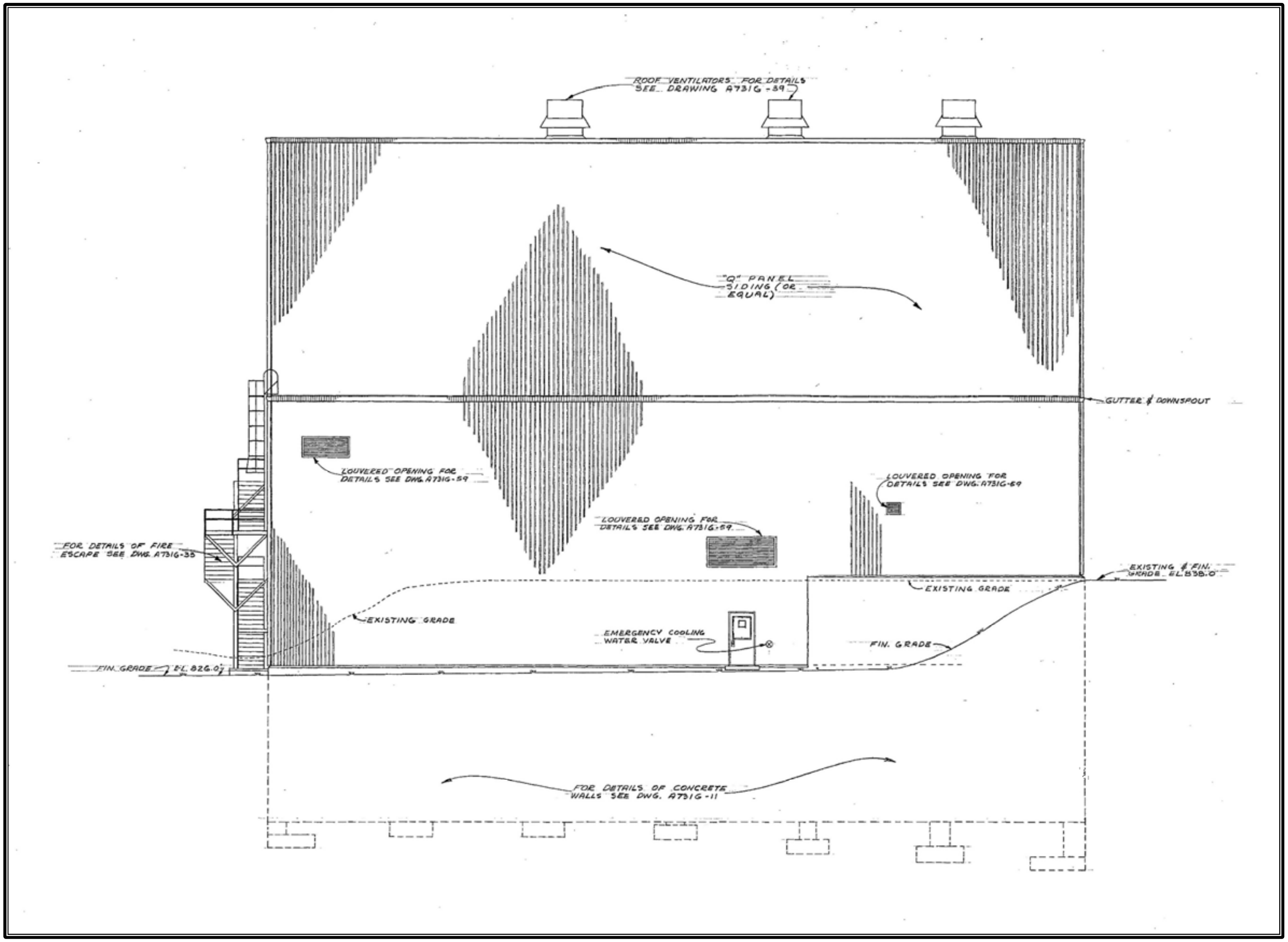


Figure 55. Portion of architectural drawing (D-22141) showing plans for the north elevation of Building 3042, circa 1955 (McPherson Company 1955d).

level.

Figure 56. Current photograph of west end of the north elevation of Building 3042 showing the Change House addition constructed circa 1957, facing south.

Figure 57. Current photograph of east end of north elevation of Building 3042, facing south. At right is the Change House addition constructed circa 1957; to the left of the addition is a set of stairs leading down to the first-floor level.

Figure 58. Current photograph of north side of Building 3042, facing west toward the Change House addition constructed circa 1957.

Figure 59. Current photograph of north elevation of Building 3042 showing concrete-lined well with two below-grade entries.

Figure 60. Current photograph of north elevation of Building 3042, facing northwest, showing the double-leaf entry in the below-grade level of the Change House addition constructed circa 1957.

Interior of Building 3042

The interior of Building 3042 is addressed by floor: basement, first floor, second floor, and third floor. This is consistent with how the building is depicted in floor plans. The reactor structure is addressed separately since it is largely freestanding within the three-story high bay and is not divided by floors in the same way as the rest of the building.

Certain interior components are common on all levels. The primary mass of Building 3042 is divided into bays by steel columns both on its north-to-south axis and on its east-to-west axis. These include five bays north-to-south and six bays east-to-west. The high-bay housing the reactor structure occupies the central three north-to-south bays; the southernmost bay contains the south wing and the northernmost bay contains the north wing. The 1957 Change House addition is located north of the five north-to-south bays, creating a partial sixth bay occupying the two westernmost east-to-west bays. Floors are of reinforced concrete of varying thicknesses to support different weight loads; to denote the load capacities, the floor is color coded in terra cotta, brown, red, and gray (Hamrick and Swanks 1968:43). Much of the flooring is bare concrete, while some areas are covered in asphalt-backed tiles or carpet. Permanent walls are generally concrete block, though certain walls are of barytes concrete in order to provide shielding from radiation. The interior walls of office and laboratory spaces were often temporary and moveable in order to reconfigure the spaces as needs arose, and composed of dividers that were metal or other materials; many of these moveable walls were later replaced.

Basement

During the ORR's active years, the basement level of Building 3042 housed a number of support and infrastructure facilities related to cooling systems, pumping systems, water demineralizing, electricity, ventilation and air filtration, storage areas, experiment work areas, and the reactor's sub-pile room (Hamrick and Swanks 1968:40). A floor plan issued in 1968 provides a detailed overview of the spaces and equipment at the basement level in the ORR (Figure 61) (ORNL 1968c). All of the basement walls are comprised of either concrete, barytes concrete, concrete block, or barytes concrete block. Entries into certain spaces are labyrinthine, to provide shielding from radioactive or “hot” materials. The basement floor is primarily comprised of poured concrete; some floor areas contain metal grates. The ceiling throughout the basement supports numerous utility pipes, light fixtures, and other equipment. All room designations provided below reflect their usage circa 1968 unless otherwise indicated.

At the center of the building at the basement level are the support substructure and various equipment located directly beneath the reactor structure; at the east end is the reactor pit/sub-pile room, west of which is the pipe chase that houses the pipes that drained the reactor’s cooling water (Figures 62–65). Both the sub-pile room and pipe chase extend further underground, more than 8 ft below the level of the basement floor (Hamrick and Swanks 1968:40). The sub-pile room is characterized by a metal grate floor, concrete walls, and a concrete ceiling. Suspended in the middle of the room is a metal platform accessible by a small metal ladder. Four metal poles travel down from a metal disc on the ceiling, comprising part of the reactor vessel, and connect to the metal platform. The concrete walls contain utility piping, valves, and wall sconces. The pipe chase features concrete walls and flooring. The concrete floor contains a metal grate. The concrete walls contain numerous pipes, valves, gauges, and dials. The ceiling supports multiple large pipes traveling north to south as well as lighting fixtures.

The surrounding substructure walls contain piping, control valves, rigs, and other equipment (Figures 66 and 67). The walls enclosing the facilities beneath the reactor are primarily of stacked barytes concrete. Lead bricks line many of the reactor substructure walls.

The 1968 drawing shows two main basement corridors running east–west on the north and south sides of the reactor structure (Figure 68). Along the south wall of the basement, moving west to east, are an elevator, a room containing motor generator sets, a Reactor Chemistry room, a stairwell, and an air-conditioning unit (Figures 69–71). The elevator opening, situated in the southwest corner, is filled with a pair of metal doors that open vertically. East of the elevator, a single-leaf entry accesses the Elevator Control Room, containing equipment. East of the Elevator Control Room is an open space followed by the Motor Generator Room, containing equipment. Further east, the Reactor Chemistry Room features painted concrete block walls; the west wall is pierced by a small entry filled with a metal sliding door (Figure 71). A stairwell containing metal stairs is east of the Reactor Chemistry Room. An air-conditioning unit occupies the southeast corner of the basement (Figure 72).

On the north side of the basement, moving west to east, are a stairwell, Laboratory, Counting Room, and two Irradiation Engineering Rooms; above the majority of the spaces on the north wall is a mezzanine level (Figure 73). Unlike most of the basement, the Laboratory and Counting Room exhibit linoleum tile floors. The Laboratory contains fumes hoods with ductwork emanating from the ceiling for exhaust purposes. Pipes travel across the ceiling and electrical conduit is affixed to the walls (Figures 74 and 75). The Counting Room walls are clad with perforated wall tiles. Ductwork suspends from the ceiling. Thick walls characterize two single-leaf, labyrinthine entries in the west wall (Figure 76). The westernmost Irradiation Engineering Room is filled with piping and equipment (Figures 77 and 78). The easternmost Irradiation Engineering Room is divided into five sections by floor-to-ceiling control panels. The ceiling is comprised of exposed steel I-beams (Figures 79–82).

At the west end of the basement the pool coolant pump, pool heat exchanger, reactor demineralizers, degasification facilities, anion and cation exchangers, and other equipment occupy the space between the reactor substructure and the west wall (Figure 83 and 84) (Hamrick and Swanks 1968:89-94). The basement also contains shop spaces east of the reactor substructure, as well as various other experimental facilities.

At the east end of the basement, a Shim Rod Drive Shop occupies the east wall (Figure 85). The east wall of the Shop contains a work bench; the south wall contains built-in storage shelves. A linear light fixture hangs from the ceiling.

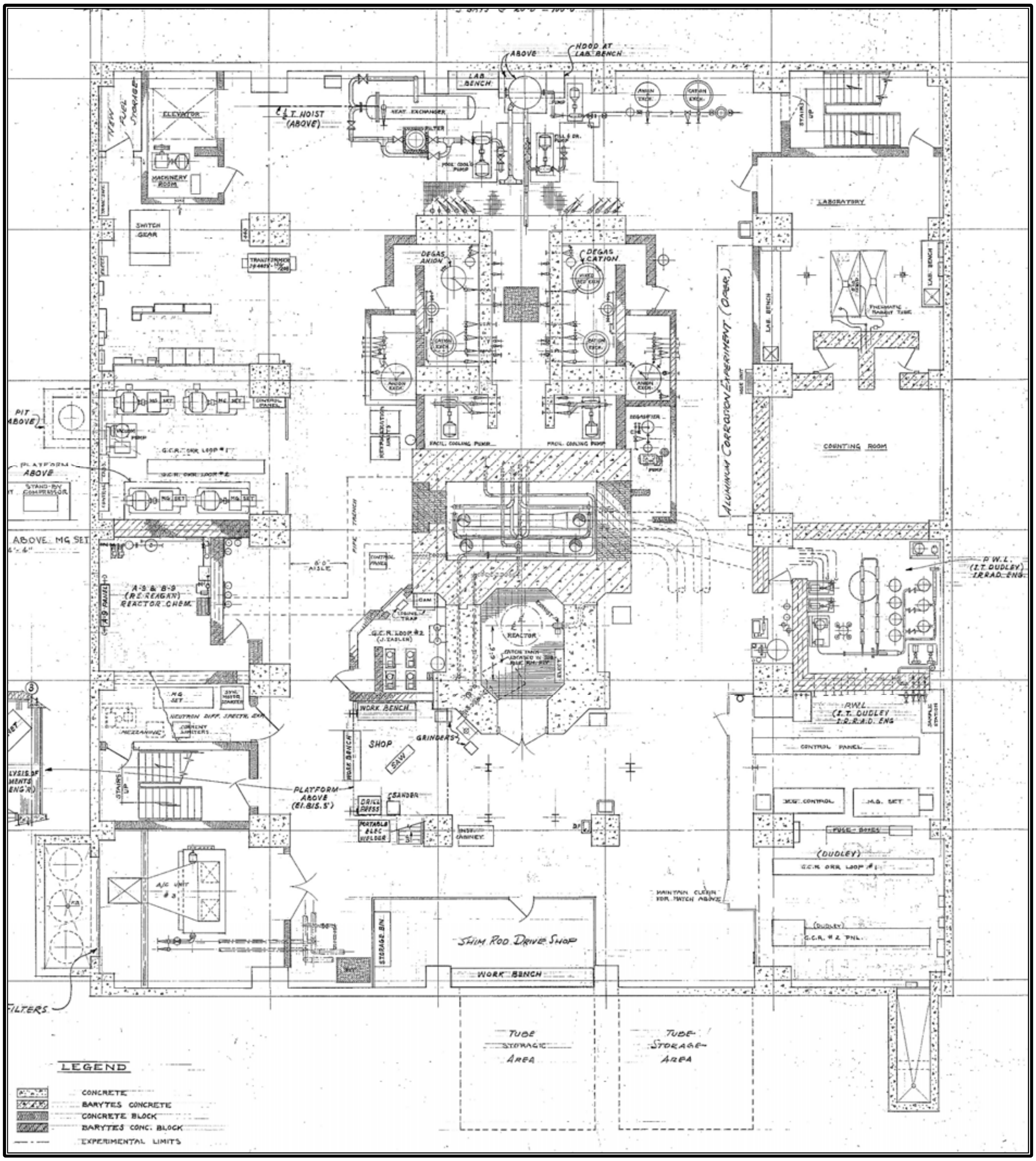


Figure 61. Architectural drawing (E-31270) showing the basement level of Building 3042, issued 1968 (ORNL 1968c).

Figure 62. Archival photograph showing the sub-pile room in the basement of Building 3042, circa 1957 (ORNL Photo 57-1477).

Figure 63. Current photograph showing the sub-pile room in the basement of Building 3042.

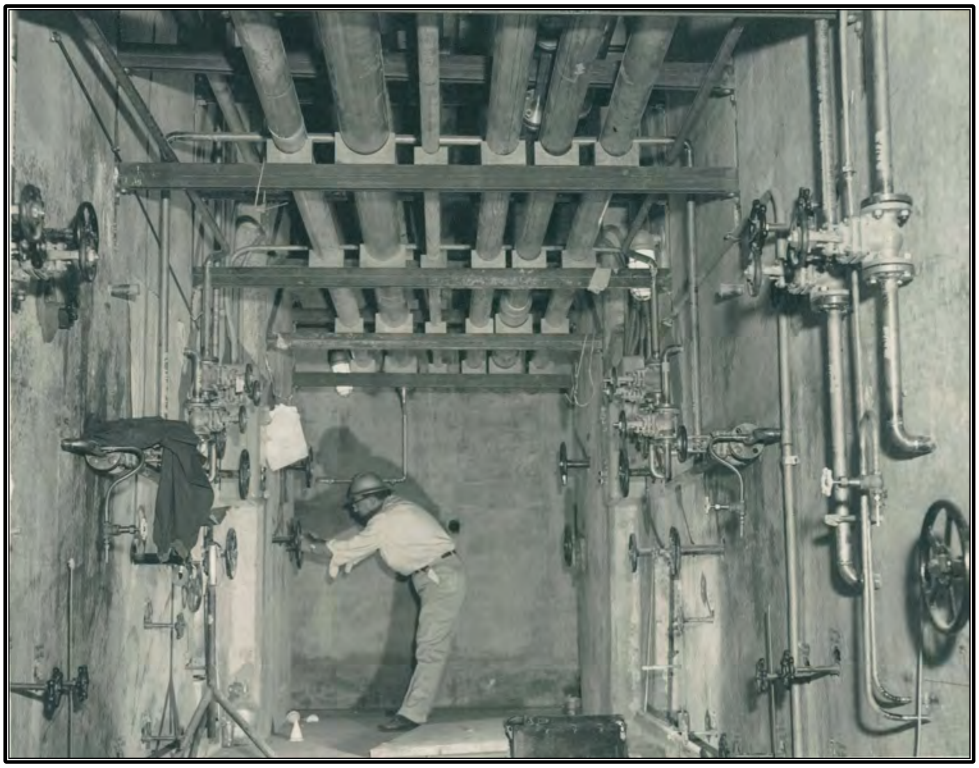


Figure 64. Archival photograph showing the pipe corridor, or pipe chase, within the reactor substructure in the basement of Building 3042, circa 1957 (ORNL Photo 57-0504).

Figure 65. Current photograph showing the pipe corridor, or pipe chase, within the reactor substructure in the basement of Building 3042.

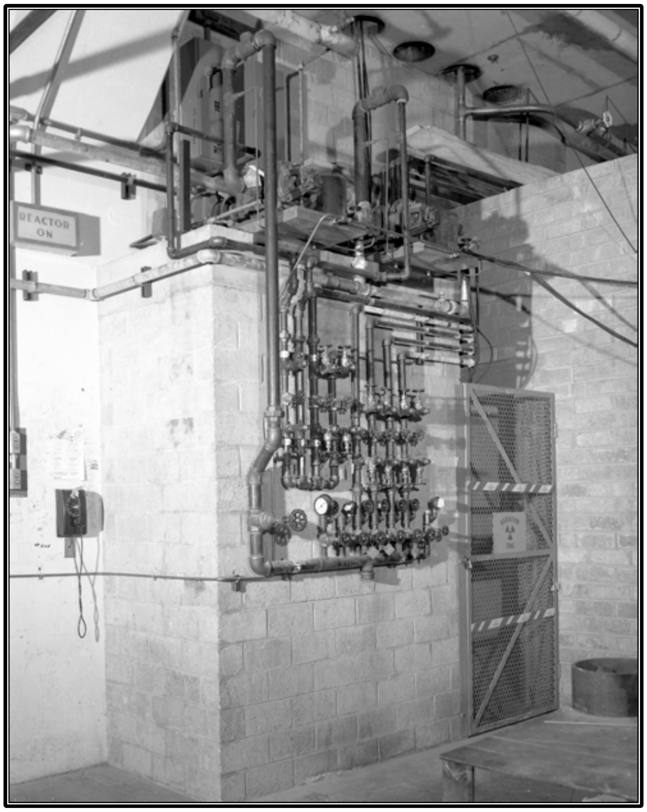


Figure 66. Archival photograph showing the southwest corner of the ORR substructure in the basement of Building 3042, including control valves mounted to the concrete block, circa 1960 (ORNL Photo 52496).

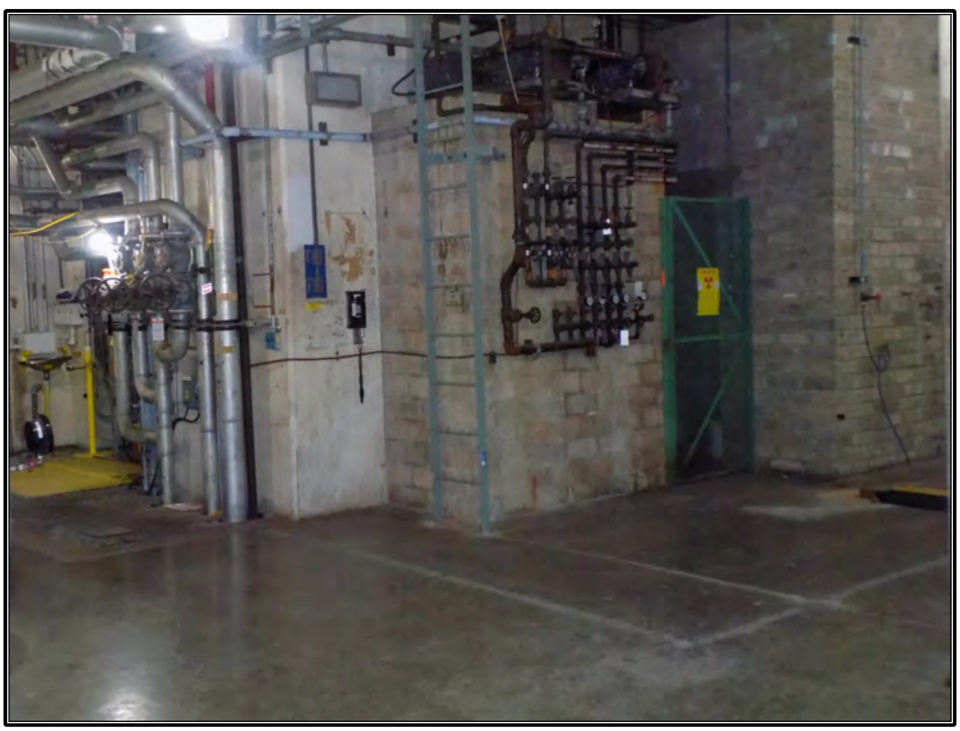


Figure 67. Current photograph showing the southwest corner of the ORR substructure in the basement of Building 3042, facing northeast.

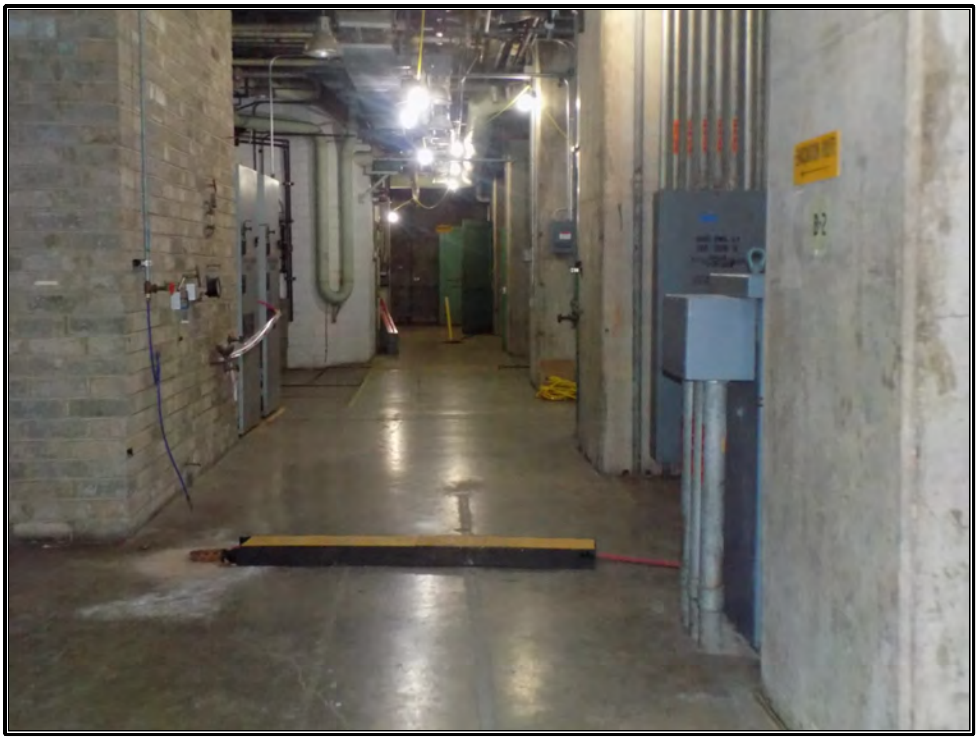


Figure 68. Current photograph showing the south basement corridor in Building 3042, facing east.

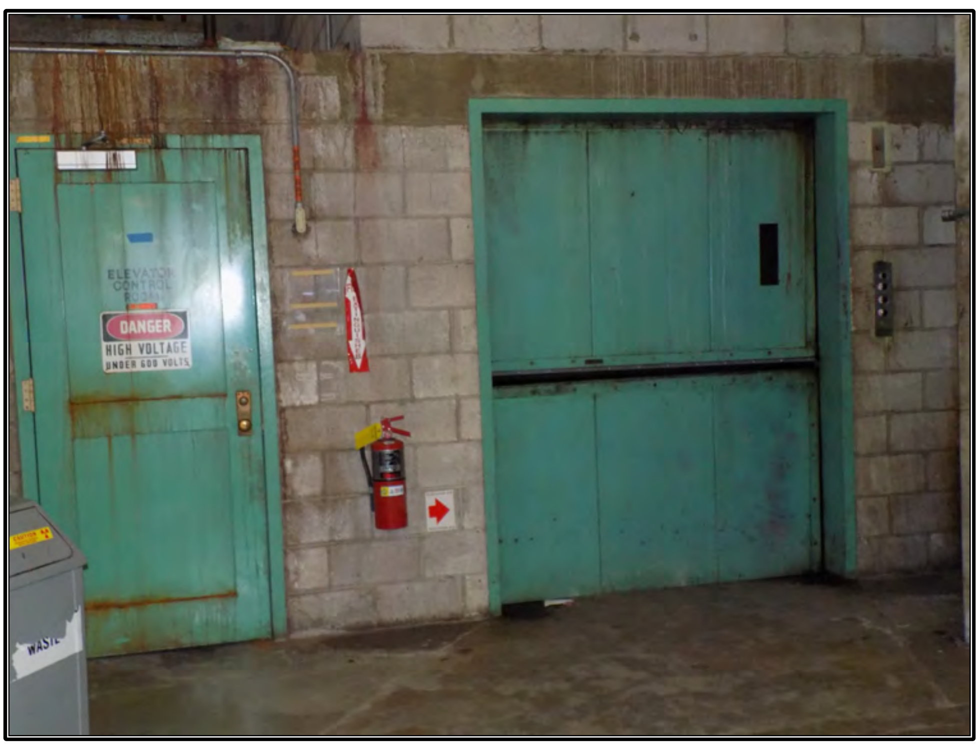


Figure 69. Current photograph of elevator at the southwest corner of the basement in Building 3042.

Figure 70. Current photograph of Machinery Room at the southwest corner of the basement in Building 3042, looking south.

Figure 71. Current photograph showing the Reactor Chemistry Room facing northwest.

Figure 72. Current photograph showing an air-conditioning unit in the southeast corner of the basement of Building 3042, facing southeast.

Figure 73. Current photograph showing the north basement corridor in Building 3042, facing west.

Figure 74. Archival photograph of fume hood in the Laboratory on the north side of the basement in Building 3042, circa 1959 (ORNL Photo 48635).

Figure 75. Current photograph of a fume hood in the Laboratory on the north side of the basement in Building 3042.

Figure 76. Current photograph of the Counting Room on the north side of the basement in Building 3042, looking southwest.

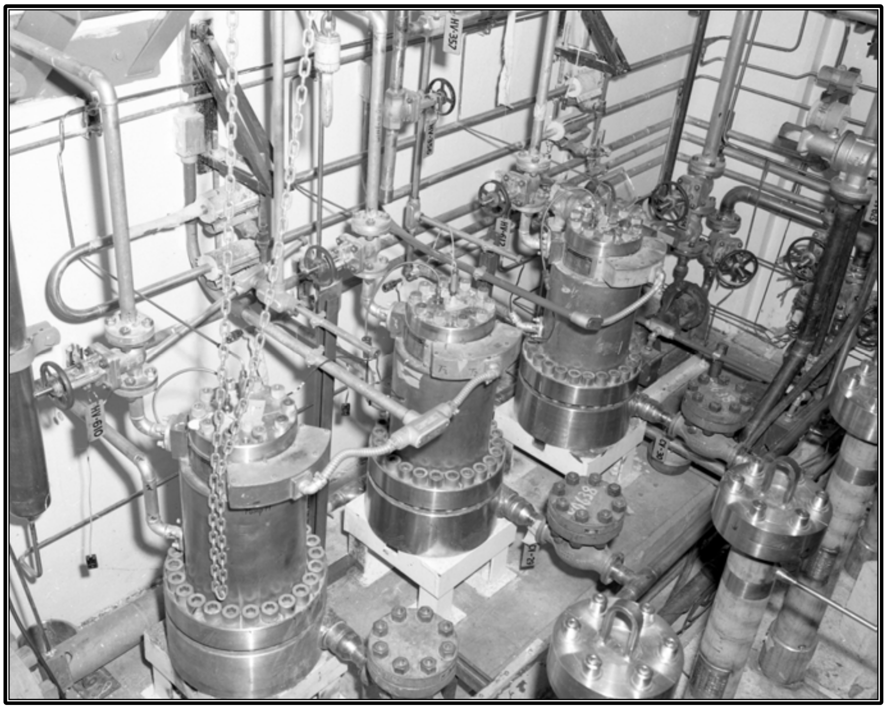


Figure 77. Archival photograph of pressurized-water loop experimental facility located in the westernmost Irradiation Engineering Room on the north side of the basement in Building 3042, circa 1959 (ORNL Photo 48272).

Figure 78. Current photograph of pressurized-water loop experimental facility located in the westernmost Irradiation Engineering Room on the north side of the basement in Building 3042.

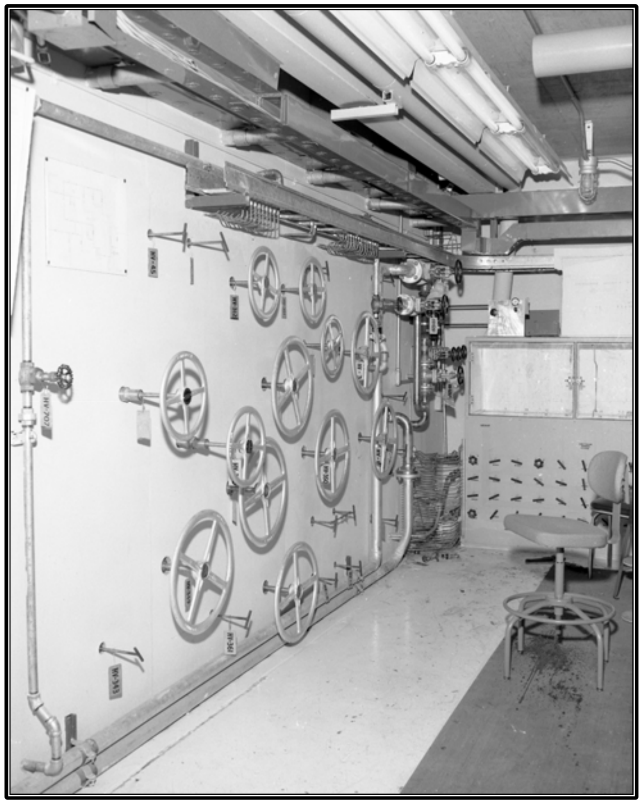


Figure 79. Archival photograph showing valve extension handles for the pressurized-water loop and the sample station located in the Irradiation Engineering Room in the northeast corner of the basement of Building 3042 (ORNL Photo 48273).

Figure 80. Current photograph showing valve extension handles for the pressurized-water loop (left), the sample station (center), and a control panel located in the Irradiation Engineering Room in the northeast corner of the basement of Building 3042, facing north.

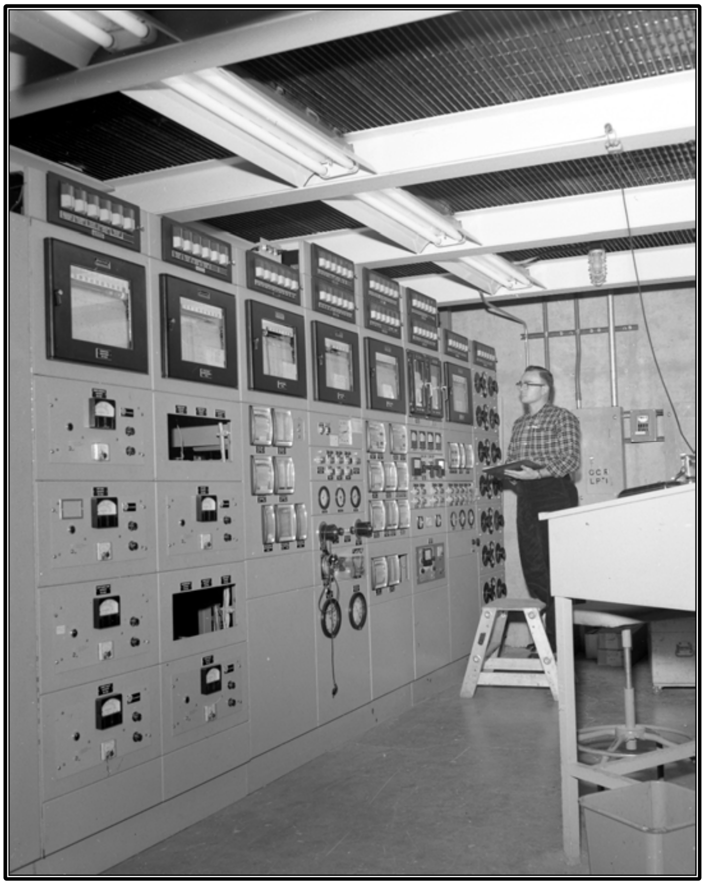


Figure 81. Archival photograph of a control panel for the GCR-ORR Loop No. 1, located in the Irradiation Engineering Room in the northeast corner of the basement in Building 3042, circa 1960 (ORNL Photo 52500).

Figure 82. Current photograph of the Irradiation Engineering Room in the northeast corner of the basement in Building 3042, looking south.

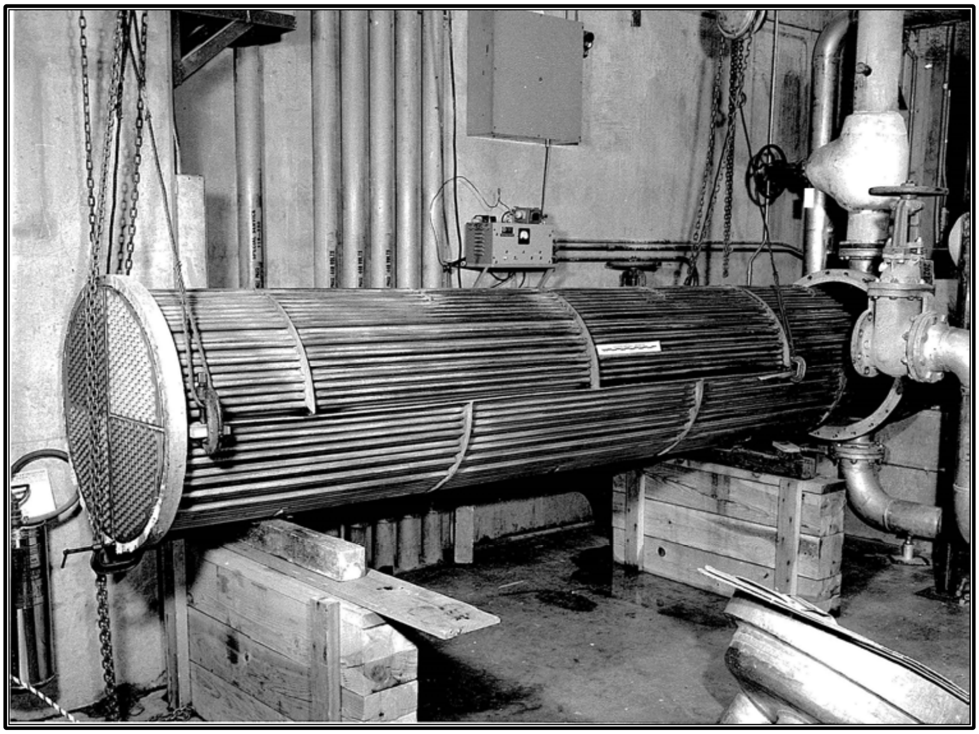


Figure 83. Archival photograph showing the Pool Heat Exchanger along the west wall of the basement in Building 3042, circa 1961 (ORNL Photo 53306).

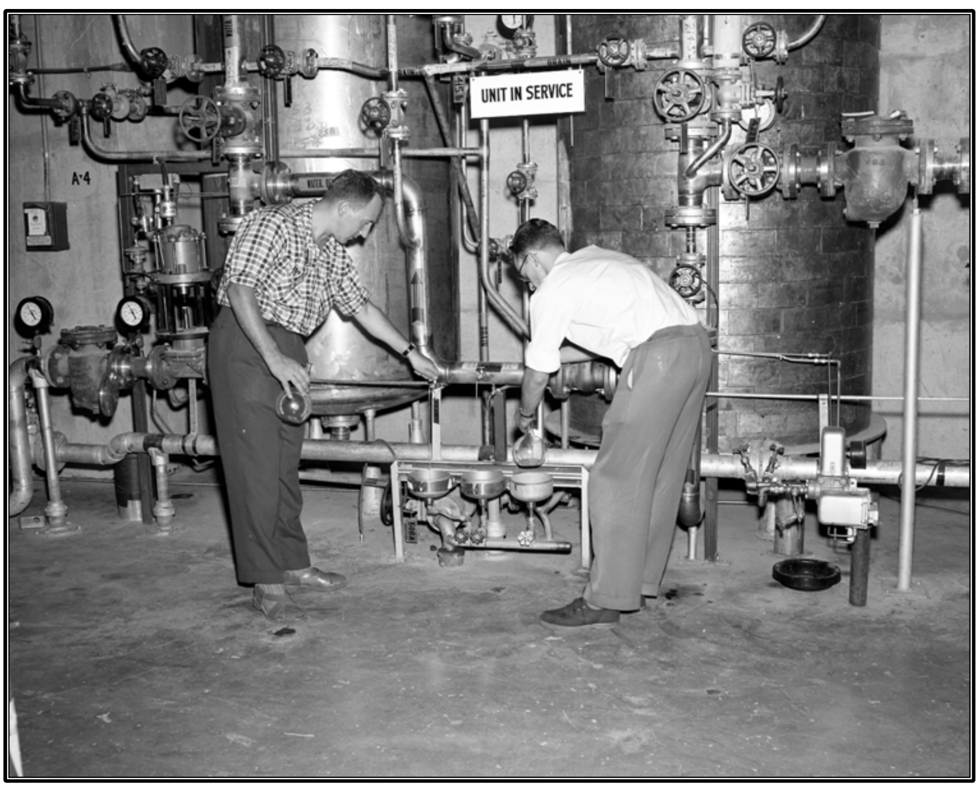


Figure 84. Archival photograph showing the anion exchanger (left) and cation exchanger (right) on the west wall of the basement in Building 3042, circa 1959 (ORNL Photo 47539).

Figure 85. Current photograph showing the Shim Rod Drive Shop in the basement of Building 3042, facing south.

First Floor

The first floor of Building 3042 is dominated by the reactor structure at the center of the high-bay section, with open space around it for experimental facilities and research areas. On the north and south sides of the building are enclosed spaces for laboratories and a shop (for the 1968 plan of the first floor, see Figure 31) (ORNL 1968a). The flooring on the first floor of Building 3042 is of exposed reinforced concrete of varying thicknesses to support different weight loads; to denote the load capacities, the floor is color coded in terra cotta, brown, red, and gray (Hamrick and Swanks 1968:43). On the north and south sides of the reactor structure are depressions in the floor over 17 ft long, 11 ft wide, and 2 ft deep, in which are large hatches to the basement. These depressions were intended to accommodate experimental rigs contained within stacked-block shielded cells, associated with each of the two large engineering facilities; the hatches allowed the rigs to be lowered into shielded cells in the basement (Hamrick and Swanks 1968:43). To provide access between the first floor and basement through which to thread various instrumentation, apparatus, and utilities, the concrete floor was pierced by a number of 4-inch, 6-inch, and 12-inch sleeves. The majority of the first-floor area is bordered by a 4-inch concrete curb to contain water from minor leaks and direct the water into the basement. The reactor structure measures 18 ft wide on its west end. The east end, which is semi-circular in order to provide room for several experimental facilities, has a 32 ft diameter. The entire reactor structure is approximately 75 ft long (Hamrick and Swanks 1968:43; ORNL 1968a, 1968b, 1968c). The reactor structure is described further below. The ceiling of the high-bay is characterized by exposed structural beams and framing. Multiple dome-shaped light fixtures hang from the ceiling. The walls along the enclosed spaces within the north and south wings are painted concrete block. Above the first floor, the second and third floor project into the high-bay. An elevated pedestrian walkway connects the north wing third floor balcony to the reactor structure (see Figures 6, 9, 10, 19, 20, 21, and 22). All room designations provided below reflect their usage circa 1968 unless otherwise indicated.

The first-floor north wing moving west to east includes an Instrument Staff Shop, Instrument and Controls Office, and an area previously designated the Physics HB-6 Room, referring to the horizontal beam hole (HB) facility designated numerically as HB-6, dominates the northeast corner. The Instrument Staff Shop, also referred to as Room 100 and previously known as the General Staff Shop, is characterized by a corner door entrance on its southwest corner. A large metal, box-shaped air-conditioning unit dominates the room (Figures 86–88). The ceiling features exposed beams and supports utility piping and dome-shaped light fixtures. Duct work travels along the ceiling and walls. The walls contain electrical conduit and metal storage cabinets occupy the wall space. A single-leaf entry, accessing the Instrument and Controls Office, pierces the east wall. Photographs of the Instrument and Controls Office were not available for this recordation. According to architectural drawings, the room is irregularly-shaped and is only accessible from the single-leaf entry in the Instrument Staff Shop (see Figure 31).

The enclosed space in the northwest corner of the first floor of Building 3042, previously designated the Physics HB-6 Room, features a drop ceiling including light panels and a linoleum tile floor. The walls are comprised of drywall. The south wall is pierced by a single-leaf entry accessing the reactor structure high-bay. The west portion of the north wall protrudes into the room. The east wall is pierced by a large metal tube that has been capped. This tube previously served for time-of-flight experimentation and extends through the east exterior wall beyond the east elevation of Building 3042, connecting to Building 3107 situated to the northeast (Figure 89).

On the northwest corner of the reactor structure, a rectangular shaped Electrical Shop is enclosed by concrete blocks. Single-leaf entries pierce the north and west walls (Figures 90 and 91). East of the Electrical Shop, equipment pertaining to the North Engineering Test Facility is located adjacent to the reactor structure. This equipment includes numerous electrical outlets, dials, gauges, and electrical conduit. Between the Electrical Shop and the North Engineering Test Facility equipment is a brick wall, including a portion comprised of lead bricks. Bricks also protrude above the brick wall, forming a cube. A brick wall is also located behind the North Engineering Test Facility equipment, between the equipment and the reactor structure (Figure 92).

Figure 86. Current photograph showing the entrance to the Instrument Staff Shop or Room 100, previously the General Staff Shop, facing east.

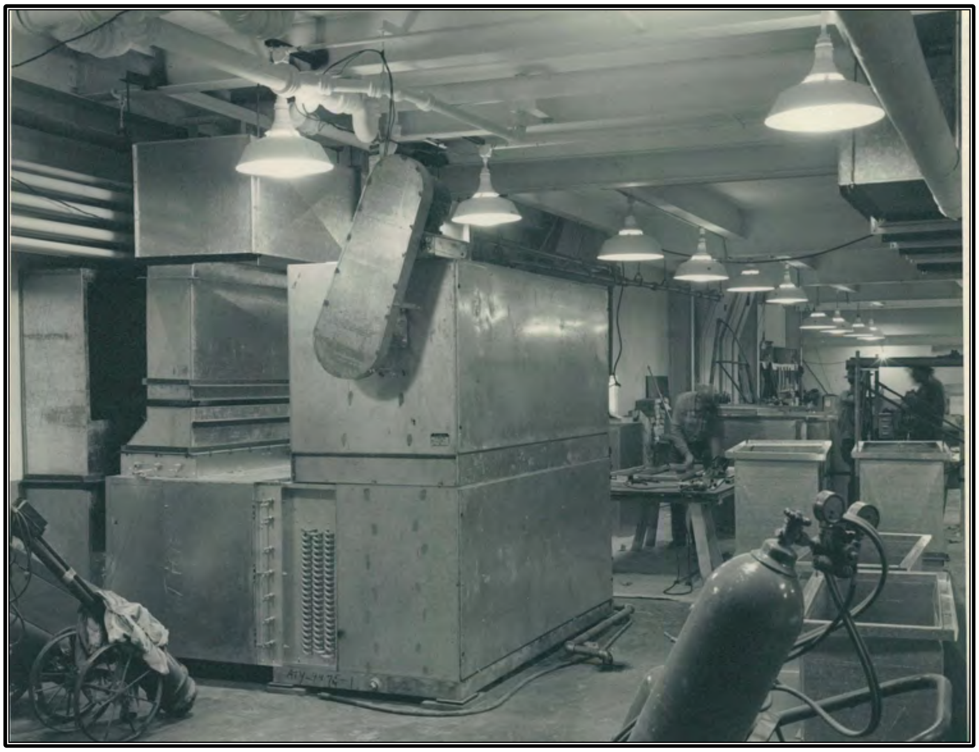


Figure 87. Archival photograph of the Instrument Staff Shop, previously the General Staff Shop, on the north side of the first floor of Building 3042, circa 1957 (ORNL Photo 57-1474). At left is a large air-conditioning unit.

Figure 88. Current photograph of Instrument Staff Shop area on the north side of the first floor of Building 3042. At left is the air-conditioning unit shown in the previous figure.

Figure 89. Current photograph of the enclosed space in the northwest corner of the first floor of Building 3042, previously designated the HB-6 Room, facing northeast. At center, time-of-flight equipment pierces the east wall and extends beyond the east elevation of Building 3042, connecting to Building 3107 to the northeast.

Figure 90. Current photograph showing the north first floor corridor, facing east. At left is the Instrument Staff Shop; at right is the Electrical Shop located on the northwest corner of the reactor structure.

Figure 91. Current photograph showing the north first floor corridor, facing west. At left is the Electrical Shop located on the northwest corner of the reactor structure.

Figure 92. Current photograph showing the North Engineering Test Facility equipment located on the north side of the reactor structure, facing southwest.

East of the reactor structure is an open space containing equipment, a large metal cylinder, and metal enclosures placed in front of the HB facilities (Figure 93). A platform including a metal railing is suspended from the east wall creating a low overhang. Stairs travel to the second floor north of the platform. Northeast of the reactor structure a hatch pierces the floor. Above the hatch, a crane suspends from the ceiling. Metal railings travel along the perimeter of the hatch (Figure 94). A metal pole, supported by a raised concrete pad, travels vertically and pierces the ceiling in the northeast corner between the room occupying the northeast corner of the first floor and the hatch space.

On the south side of the reactor structure, a containment cell is enclosed by concrete walls. This containment cell enclosed equipment used for the GCR-ORR Loop No. 2. The containment cell features a corner viewing window on its southeast corner. The south wall of the containment cell is pierced by a large port filled with a metal plug. Instruments, dials, and other equipment are affixed to the south and east walls of the containment cell. The south wall of the containment cell also contains fuse boxes and other electrical equipment. A glovebox sits adjacent to the south wall of the containment cell west of the infilled port (Figure 95). On the west end of the containment cell, a Decontamination Room and Air Lock provide access to the interior of the containment cell. The Air Lock, accessed by a single-leaf entry in its south wall, exhibits metal walls comprised of exposed beams and metal sheeting. The north wall of the air lock is pierced by a single-leaf entry filled with a metal door accessing the Decontamination Room. The Decontamination room is lined with stainless steel (Figure 96).

The first-floor south wing moving west to east includes an elevator, Instrumentation Room, an area containing a large air-conditioning unit and GCR-ORR Loop No. 2 Instrumentation, and a Magnetic Analysis of Fission Fragments HB-1 Room in the southeast corner. The elevator entry is filled with a pair of metal doors that open vertically. East of the elevator entry, the west wall of the Instrumentation Room extends and is pierced by a single-leaf entry (Figure 97). The Instrumentation Room features a linoleum tile floor and the ceiling exhibits exposed beams. Linear fluorescent light fixtures hang from the ceiling. Utility piping travels along the ceiling and south wall. The upper portion of the walls are clad with perforated tiles. The lower portions of the north and west walls are painted concrete block; the lower portions of the south and east walls are drywall. The west, south, and east walls contain electrical conduit; the south and east walls contain electrical boxes. The west wall is pierced by a single-leaf entry filled with a wood door exhibiting a single light that accesses the area by the elevator. The northeast corner protrudes into the room (Figure 98). South of the Instrumentation Room, an enclosed space contains a large air-conditioning unit that is connected to numerous pipes that pierced the floor leading into the basement. The ceiling of this space supports a box-shaped fluorescent light fixture and utility piping. This space is characterized by low-hanging ductwork. The south wall contains numerous utility pipes and electrical conduit. The north wall is pierced by a double-leaf entry (Figure 99).

The southeast corner of the first floor is occupied by a room previously designated as the Magnetic Analysis of Fission Fragments HB-1 Room. This room features a drop ceiling including light panels and a concrete floor. A single-leaf entry filled with a wood door featuring a single light pierces the north wall. According to architectural drawings, a second entry pierced the west wall of the room in 1968 (ORNL 1968a). The south and east walls are comprised of drywall; the west and north walls are comprised of concrete block. The east wall exhibits an indention in the northeast corner that contains an electrical box and pipes containing electrical conduit (Figure 100).

West of the reactor structure, a corridor travels north to south. The west wall of the corridor is painted concrete and contains pipes and metal boxes. Low hanging ductwork travels from the reactor structure to the west wall. The ceiling features exposed structural beams and supports utility piping traveling north to south and connecting to vertical utility piping that pierces the concrete floor (Figure 101).

Circa 1957, the three-story Change House addition was constructed at the northwest corner of the building, the first floor of which was used as an equipment area containing a compressor and generator equipment (Figure 102) (ORNL n.d.a, 1963). The floor is poured concrete and the ceiling features exposed structural beams. Utility pipes travel across the ceiling and several connect to the equipment that dominates the floor space. The walls are painted concrete and support electrical conduit and numerous fuse boxes. A double-leaf entry filled with two metals doors featuring two lights each pierces the east wall, accessing the well on the north elevation. A large box-shaped fan also pierces the east wall just east of the diesel-powered generator (Figures 103 and 104).

Figure 93. Current photograph showing the south side of the first floor and reactor structure in Building 3042, facing northeast.

Figure 94. Current photograph showing the hatch located in the northeast corner of the high-bay on the first floor of Building 3042, facing east.

Figure 95. Current photograph showing the southeast corner of the containment cell on the south side of the reactor structure, facing northwest. At left, a metal plug shields the access to a large port piercing the south wall of the containment cell.

Figure 96. Current photograph showing the Air Lock providing access to the Decontamination Room which provides access to the interior of the containment cell on the south side of the reactor structure, facing north.

Figure 97. Current photograph showing the elevator door in the southwest corner of the first floor of Building 3042, facing south. At left is an entry accessing the Instrumentation Room.

Figure 98. Current photograph showing the Instrumentation Room on the first floor of Building 3042, facing southeast.

Figure 99. Current photograph showing the enclosed space in the south wing containing a large air-conditioning unit, facing west.

Figure 100. Current photograph showing the room occupying the southeast corner of the first floor of Building 3042, facing northeast.

Figure 101. Current photograph showing the corridor between the reactor structure and the west wall of the first floor in Building 3042, facing north.

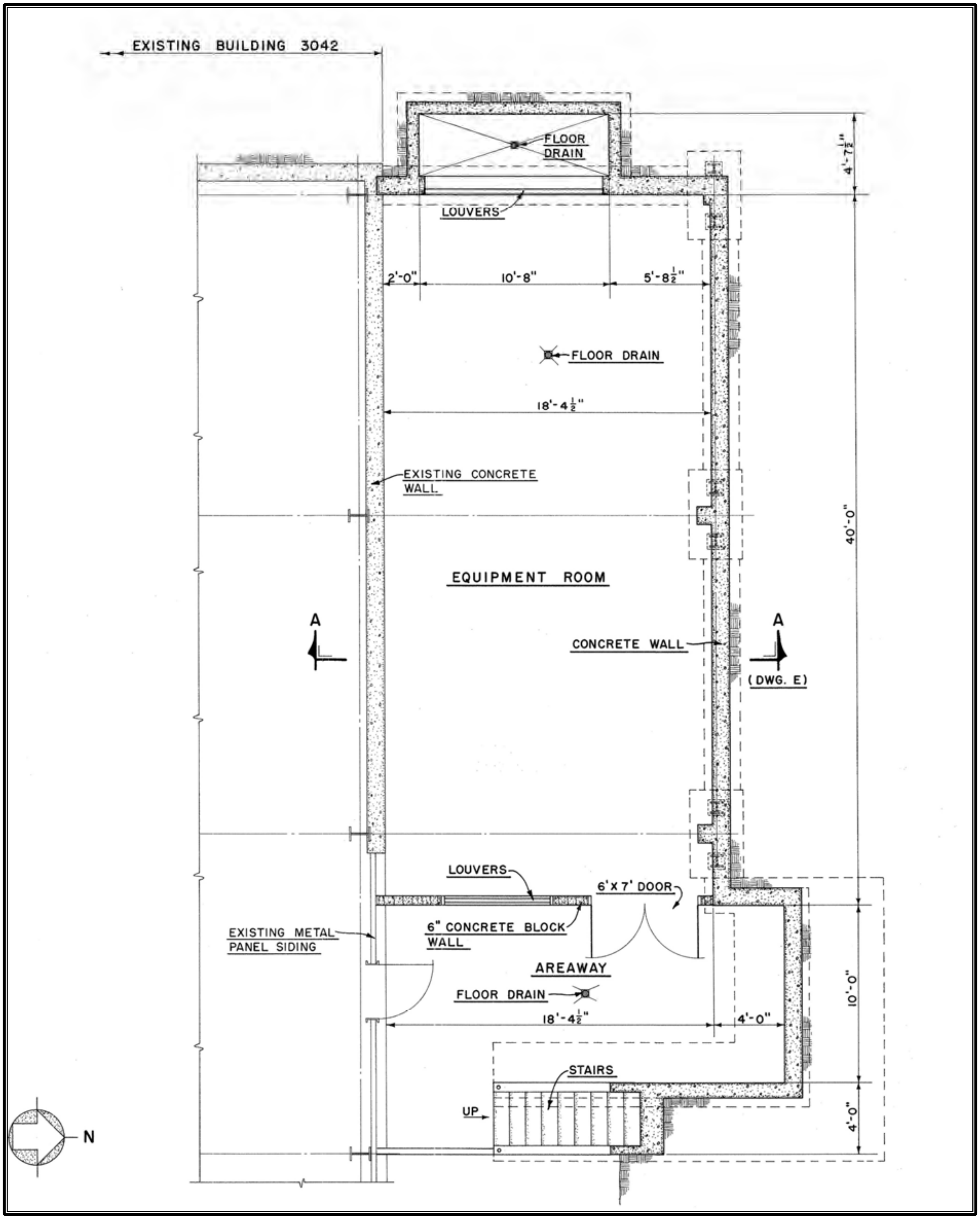


Figure 102. Architectural drawing (C-28304) of the first floor of the Change House addition to Building 3042, circa 1957 (ORNL n.d.a).

Figure 103. Current photograph of first floor of the northwest addition to Building 3042, looking south. At right is a compressor; at left is a generator.

Figure 104. Current photograph showing the diesel-powered generator and box-shaped fan on the first floor of the Change House addition to Building 3042, facing southeast.

Second Floor

Since Building 3042 is built into a hillside, the second floor is at ground level on the west side of the building. As with the first floor, the flooring is of reinforced concrete on steel framing, varying in thickness to accommodate different weight loads, with color coding to denote the different load sections. Permanent walls are of concrete block; changeable walls, such as those for offices, previously utilized partitions, comprised of metal and other materials. These moveable walls were replaced with permanent ones at an unknown date and are presently comprised of drywall, faux wood paneling, or gypsum board.

Like the first floor, much of the second floor is open space, dominated by the reactor structure in the central high-bay portion of Building 3042. On the north and south sides of the building are wings containing rooms along the north and south walls, accessed by elevated walkways connected to the reactor structure. Stairs travel between the three floors of the building, the reactor structure, and the elevated walkways. On the west end of the building, the service doors on the west elevation open into a Truck Bay that connects the north and south wing corridors at the second floor level. On the east end of the building, the second floor is open to the reactor structure in between the north and south wings, excepting a platform and catwalk accessible by stairs from the first floor (Figure 105; see Figure 94) (ORNL 1968b). All room designations provided below reflect their usage circa 1968 unless otherwise indicated.

The second-floor north wing moving west to east includes a stairwell, Room 201 (a women's restroom); Room 203 (a men's restroom); Room 205 (a service closet); a large enclosed space encompassing Rooms 207, 209, and 211 (the entirety of which was used as a Control Room for in-pile experiments); and Room 213 (previously shared by the Chemistry and Physics Divisions) (ORNL 1968b). These rooms are connected by the second-floor north corridor which travels west to east through the building. This corridor is flanked by a metal railing and overlooks the high-bay on its south side. At its approximate midpoint, a stairwell departs from the second-floor north corridor and travels up to the balcony on the reactor structure (Figure 106).

The women's restroom, or Room 201, features a tile floor and painted concrete block walls. The south wall is pierced by a single-leaf entry accessing the second-floor north corridor. The west wall is dominated by two shower stalls. The north wall contains utility piping. The east wall supports a mirror featuring an overhead fluorescent light fixture and a cabinet featuring two sinks. Electrical conduit travels across the east wall (Figure 107). The men's restroom, or Room 203, features a tile floor, painted concrete block walls, and three stalls. The south wall is pierced by a single-leaf entry filled with a wood door featuring a louvered opening that accesses the second-floor north corridor. The west wall is dominated by three restroom stalls. The north wall is pierced by a single-leaf entry featuring a panic bar that accesses the Change Room in the circa 1957 Change House addition. The south wall is pierced by a single-leaf entry accessing the second-floor north corridor. The west wall contains two wall-mounted sinks, two mirrors, paper towel and soap dispensers, and utility piping (Figure 108). East of the men's restroom, the service closet, or Room 205, features a poured concrete floor, concrete block walls, and a concrete ceiling (Figure 109). A water heater dominates the northwest corner of the room. The south wall is pierced by a single-leaf entry accessing the second floor north corridor. The west wall contains a sink and utility piping. The north and east walls contain utility piping as well as valves and gauges pertaining to the water heater. The east wall also contains a wood shelving unit.

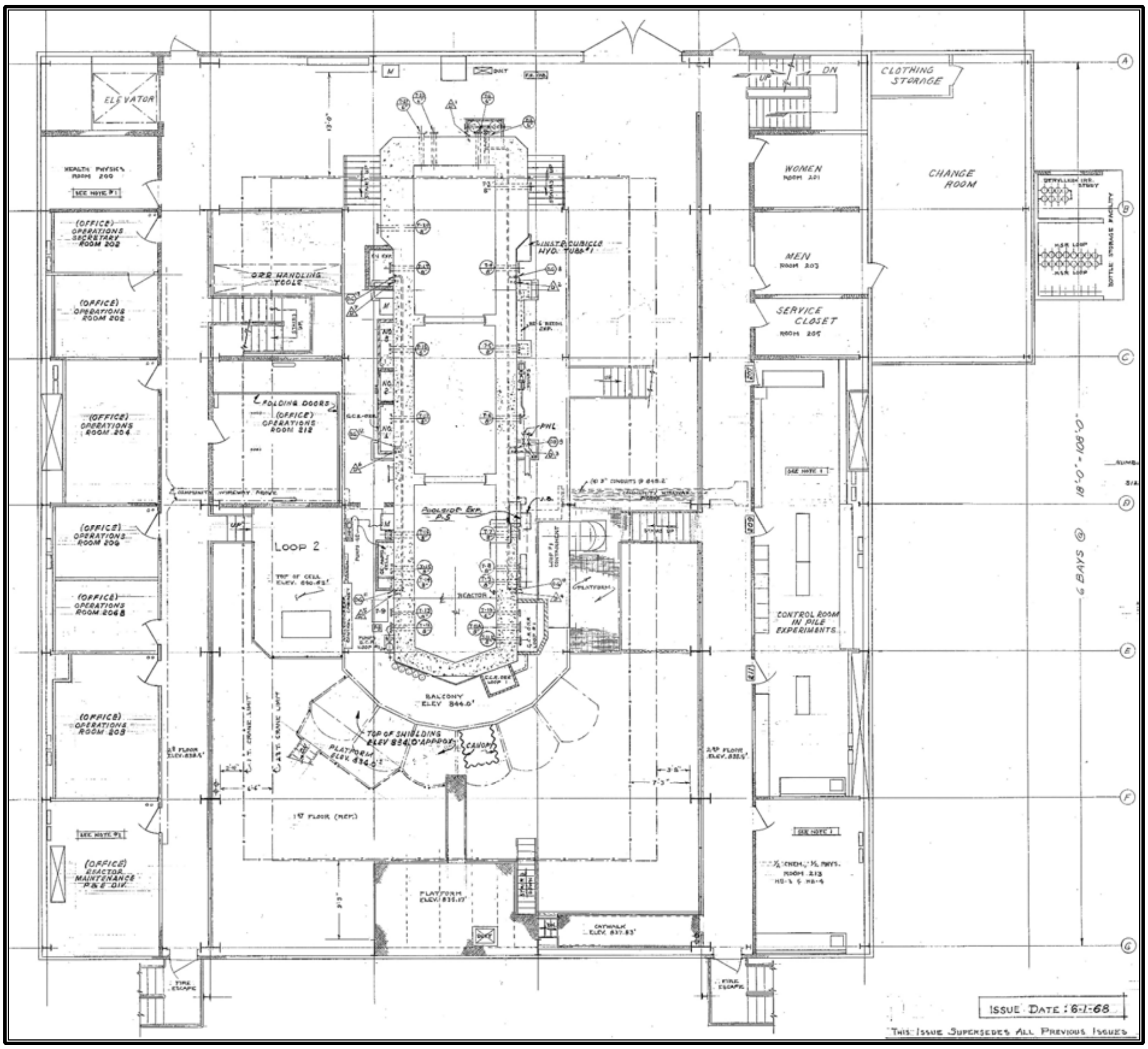


Figure 105. Architectural drawing (E-31272) of the second floor of Building 3042, issued 1968 (ORNL 1968b).

Figure 106. Current photograph showing the north corridor on the second floor of Building 3042, facing east. The stairwell leading to the reactor structure is in the background at right.

Figure 107. Current photograph of women's restroom in the northwest portion of the south wing on the second floor of Building 3042, showing locker area and showers.

Figure 108. Current photograph showing the men's restroom in the northwest corner of the second floor of Building 3042, facing south.

Figure 109. Current photograph of janitor's closet with hot water heater, located in the northwest corner of the second floor of Building 3042, facing south.

East of the restrooms and service closet, the Control Room for in-pile experiments occupies the majority of the north wing. Three single-leaf entries access this rectangular room from the second-floor north corridor. Each of the three doors are marked with a different room number on the 1968 floor plan. Presumably, this room was subdivided into three rooms based upon in-pile experiment activities. The westernmost door denotes Room 207; the central door denotes Room 209; and the easternmost door denotes Room 211. The Control Room for in-pile experiment is presently open space as the majority of the equipment has been removed. It exhibits a linoleum tile floor and a drop ceiling, featuring linear fluorescent light fixtures and metal grates. Ventilation and piping also suspends from the ceiling. The south and west walls are comprised of painted concrete block; the north and east walls are comprised of drywall. The south wall is pierced by three single-leaf entries, all filled with wood doors featuring louvered openings. The south and west walls contain electrical conduits and outlets. The north wall contains numerous fuse boxes, electrical conduit, pipe containing electrical conduit, a wood shelf, and other electrical boxes. At the west and east ends of the north wall, the wall protrudes into the room; the protrusion on the east end is obstructed by a metal railing along its perimeter. The east wall contains electrical conduit and utility piping (Figure 110).

Room 213 occupies the northeast corner of the second floor of Building 3042. The floor is coated concrete and the ceiling is dominated by a large metal box. The south wall is pierced by a single-leaf entry accessing the second-floor north corridor, is comprised of concrete block, and contains electrical conduit. The west concrete block wall is shorter than the south wall, allowing ductwork to travel between Room 213 and the Control Room for in-pile experiments located to the west (Figure 111). The north wall is comprised of drywall and contains electrical conduit, utility piping, and a metal shelf. The east wall features exposed steel beams and contains electrical conduit.

At its east end, the second floor north corridor provides access to a catwalk located on the east wall of Building 3042. This catwalk leads to stairs accessing the first floor as well as a suspended platform (Figure 112). The remaining portion of the east end of the second-floor level in Building 3042 is open to the high-bay and first floor. An exterior single-leaf entry is located at the east end of the second-floor north corridor and accesses the northern fire escape on the east elevation (see Figure 44).

A single room, Room 212, an Operations Divisions Office, is adjacent to the reactor structure on its south side. This room is accessed on its south wall from the only single-leaf entry along the north side of the second-floor south corridor. This entry is filled with a wood door featuring a single light. The floor in Room 212 is linoleum tile and the ceiling supports utility piping and linear fluorescent light fixtures. The walls are clad with perforated tiles. The south wall contains the entry, electrical conduit, utility piping, and a fuse box. Above the fuse box, a metal shelf connects to three pipes that travel vertically to the ceiling. The west wall contains utility piping and a metal rack including straps. The north wall contains utility piping, electrical conduit, and electrical boxes. A small opening pierces the north wall near the ceiling and is filled with two stacked wood doors. An exposed metal beam travels horizontally along the north wall. The east wall contains electrical conduit and a fuse box. Glove boxes and other equipment occupy Room 212 (Figure 113).

The second-floor south wing moving west to east includes an elevator shaft in the southwest corner, Room 200 (the Health Physics Room), Room 202 (Operations Division Secretary Office), a second room designated Room 202 (an Operations Division Office), Rooms 204, 206, 206B, and 208 (all Operations Division Offices), and Room 210 (a Reactor Maintenance Plant and Equipment Division Office) (see Figure 105). These rooms are connected by the second-floor south corridor which overlooks the high-bay on its north side and is flanked with a metal railing. At its approximate midpoint, a metal staircase connects to the second-floor south corridor and leads up to a balcony on the reactor structure (Figure 114). A second staircase leads from the second-floor south corridor to the top of the GCR-ORR Loop No. 2 containment cell adjacent to the south side of the reactor structure (see Figure 105). Ductwork travels east to west along the ceiling of the south corridor.

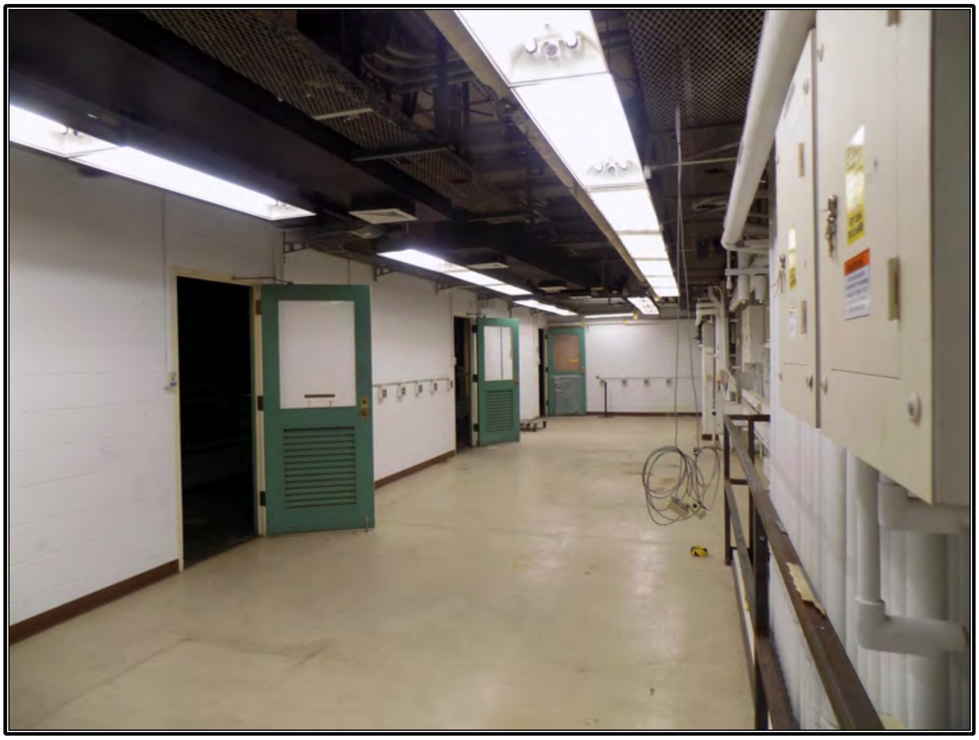


Figure 110. Current photograph showing the Control Room for in-pile experiments, facing southwest.

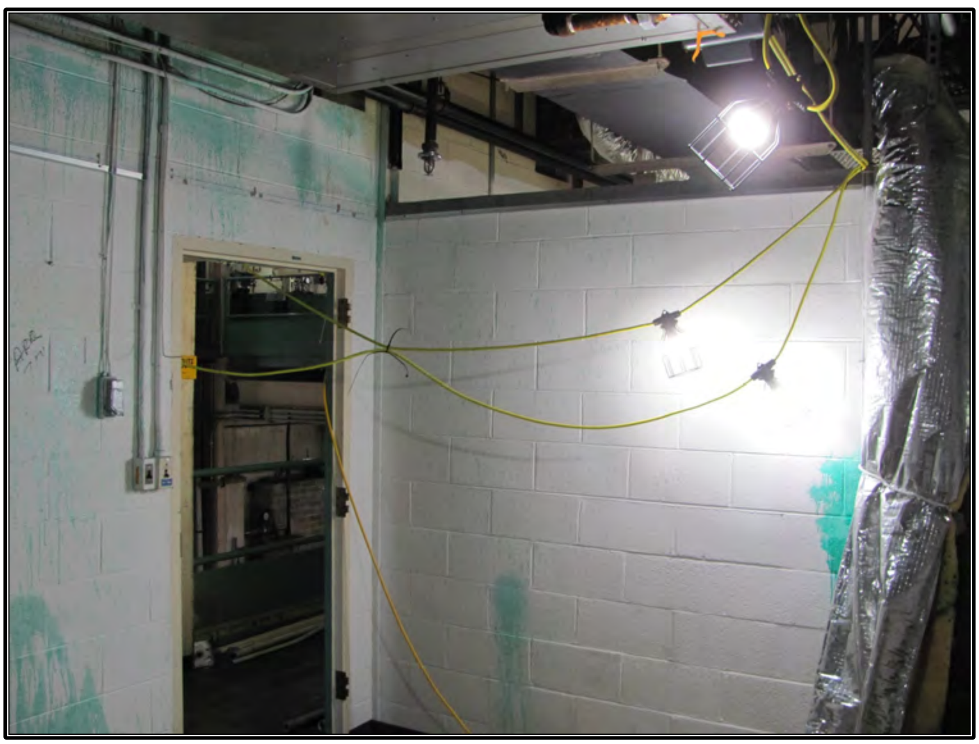


Figure 111. Current photograph showing Room 213 in the northeast corner of the second floor of Building 3042, facing southwest.

Figure 112. Current photograph showing the catwalk (at left) and the suspended platform (at center) on the east wall of Building 3042 at the second-floor level, taken from the east end of the north corridor, facing south.

Figure 113. Current photograph showing Room 212 located along the south side of the reactor structure at the second-floor level of Building 3042, facing northwest.

Figure 114. Current photograph of the south corridor on the second floor of Building 3042, facing east.

The elevator opening located in the southwest corner of the second floor is filled with a pair of metal doors that open vertically. This opening is surrounded by a concrete block wall. East of the elevator, the south wall of the second-floor south corridor is comprised of gypsum board and contains equipment and a fire alarm box. Further east, the south wall of the second-floor south corridor is comprised of painted concrete block (Figure 115).

In total, the south wall of the second-floor south corridor is pierced by seven single-leaf entries accessing the individual offices listed above. Photographs of Room 202 or the second space designated Room 202 were not identified for this recordation. Rooms 204, 206, 206B, and 208, all Operations Division Offices, are characterized by linoleum tile floors and drop ceilings including light panels and ventilation. The walls are comprised of either painted concrete block or faux wood paneling and contain electrical conduit and loudspeakers. Rooms 204, 206, and 208 exhibit wall alcoves containing shelving and/or electrical equipment. Room 204 features a long horizontal alcove on its south wall (Figures 116 and 117).

The southeast corner of the second floor of Building 3042 is occupied by the Reactor Maintenance Plant and Equipment Division Office. This office features a linoleum tile floor. Panels, ventilation, and linear fluorescent light fixtures suspend from the ceiling. The west and north walls are concrete block; the east and south walls are gypsum board. The north wall is pierced by a single-leaf entry filled with a wood door featuring a louvered opening that accesses the second-floor south corridor. A wood cabinet, loud speaker, and electrical conduit are affixed to the north wall. The east wall is dominated by a lab bench featuring cabinets, drawers, and a sink. Above the lab bench, utility pipes travel horizontally across the east wall and turn along the south wall. The south wall is dominated by large metal ductwork. Fuse boxes are affixed to the south wall west of the ductwork. The west wall contains electrical conduit (Figure 118).

At the east end of the second-floor south corridor, a single-leaf entry filled with a metal door featuring one light provides access to the southern fire escape on the east elevation (Figure 119; see Figure 45).

Both the north and south second-floor corridors connect to the Truck Bay, or Truck Alley, at their west ends, where the double-leaf service entry pierces the west elevation at grade. This space was utilized to load and unload equipment related to the reactor pools (Figure 120) (Hamrick and Swanks 1968:44; ORNL 1954e, 1968b). Two sets of stairs access the reactor structure from the Truck Bay, both on its north and south side (Figure 121).

In 1957, the three-story Change House addition was constructed at the northwest corner of the building, the second and third floors of which functioned as a men's change-room facility and contained lockers, showers, and restroom facilities; a doorway connected the change room to an existing men's restroom in the north wing of the primary building mass (Figure 122; see Figures 25-29) (ORNL n.d.d). More limited women's change facilities were incorporated into the women's restroom in the north wing of the primary building mass (see Figure 107).

The second floor of the Change House addition is a single room. A circa 1968 architectural drawing indicates there is a small closet for clothing storage in the southwest corner; however, current photographs indicate these walls may have been removed. The floor is coated concrete and the ceiling exhibits exposed structural beams. The west, north, and east walls are clad with gypsum board and the south wall is comprised of the original corrugated metal exterior siding which has been painted. A single-leaf entry accessing the men's restroom in the north wing of Building 3042 pierces the south wall. An exterior single-leaf entry pierces the west wall. Six rows of lockers emanate from the south wall. Moving west to east, two lavatories, two urinals, two water closets, and six shower stalls are located along the north wall. A furnace and hot water heater occupy the east wall (Figures 123 and 124).

Figure 115. Current photograph showing the elevator door in the southwest corner of the second floor of Building 3042, facing south.

Figure 116. Current photograph showing Room 204 on the second floor of the south wing in Building 3042, facing southwest.

Figure 117. Current photograph showing Room 208 on the second floor of the south wing in Building 3042, facing southeast.

Figure 118. Current photograph of the Reactor Maintenance Plant and Equipment Division Office in the southeast corner of the second floor of Building 3042, facing southeast.

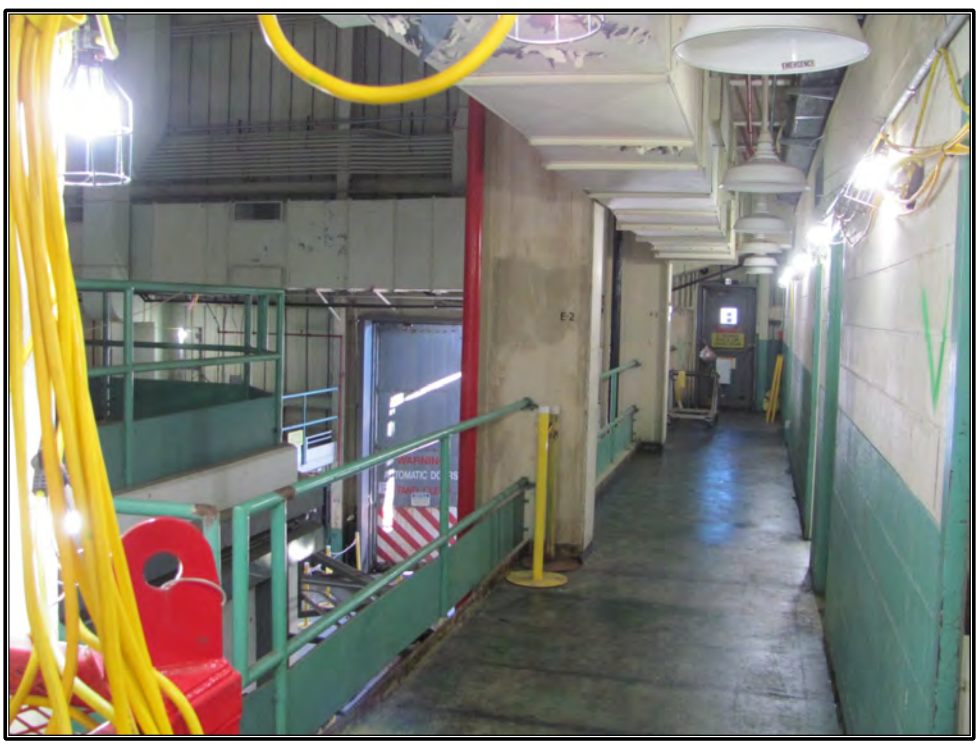


Figure 119. Current photograph of the east end of the south corridor, facing northeast. At right the single-leaf entry accesses the fire escape on the east elevation; at left the service truck entry accesses the first floor of Building 3042 from the east elevation.

Figure 120. Current photograph of second floor of Building 3042, looking northeast from the service entry on the west side of the building. In the foreground is the truck alley. At left is a restroom. At upper right is a suspended walkway connecting the third floor of the north wing to the reactor structure.

Figure 121. Current photograph showing a staircase that leads from the Truck Bay on the west side of Building 3042 at the second floor level, providing access between the service entry on the west elevation at grade and the balcony of the reactor structure, facing east.

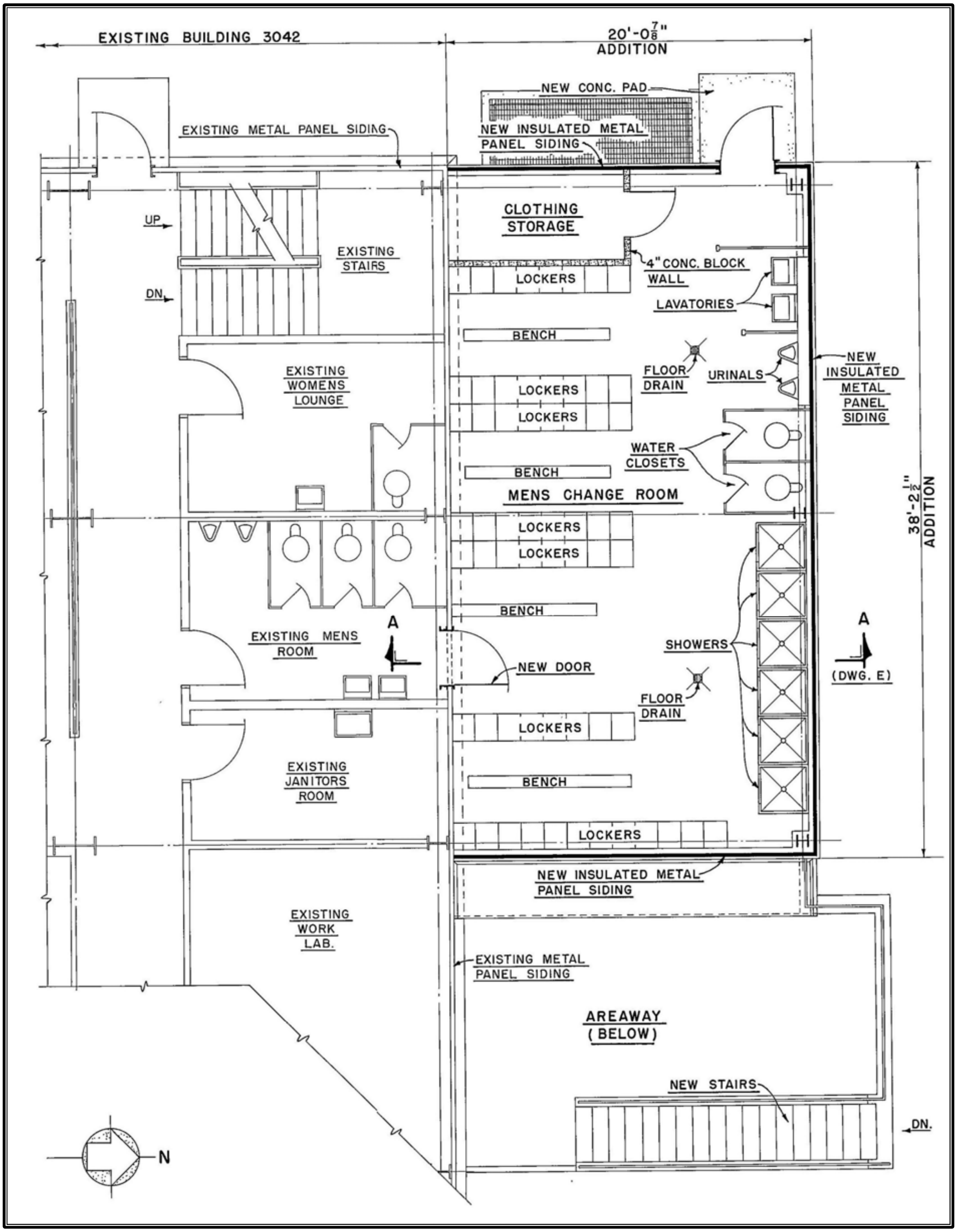


Figure 122. Architectural drawing (C-28305) of the second floor of the northwest addition to Building 3042, circa 1957 (ORNL n.d.d).

Figure 123. Current photograph of lockers in the men's change room on the second floor of a northwest addition made to Building 3042 in 1957; in the background is the doorway into the men's restroom.

Figure 124. Current photograph of showers in the men's change room on the second floor of a northwest addition made to Building 3042 in 1957.

Third Floor

As with the first and second floors, the high-bay portion of the third floor is open to the ceiling to accommodate the reactor structure. Along its north, south, and west sides, Building 3042 includes a third-floor level (Figure 125) (ORNL 1968d). The flooring at this level is of reinforced concrete on steel framing, varying in thickness to accommodate different weight loads, with color coding to denote the different load sections like on the first and second floors. Permanent walls are of concrete block; changeable walls, such as those for individual offices and laboratories, utilized insulated partitions of metal and other materials. These walls were insulated because the rooms on the third floor were air conditioned (Hamrick and Swanks 1968:45, 47). These moveable walls were either replaced with more permanent gypsum board or removed entirely at an unknown date prior to this recordation. All room uses provided below reflect their usage circa 1968 unless otherwise indicated.

The third-floor north wing moving west to east includes a walkway; stairwell; Rooms 301, 303, 305, and 307 (all Operations Offices); and Room 309, the Control Room. In the northwest corner of the third-floor north wing, an air-conditioning unit equipment room is located within the Control Room. These rooms are connected by the third-floor north corridor which travels west to east through the building. The corridor is flanked by a metal railing and overlooks the high-bay on its south side. Near its approximate midpoint, a walkway departs southward from the third-floor north corridor, connecting to the reactor structure. Just east of the walkway, a stairwell connects to the balcony of the reactor structure. A metal grated wall that previously contained a door is located at the west end of the third floor south corridor (Figure 126). The third-floor north corridor terminates at its east end at a single-leaf entry accessing Room 309. The corridor then turns south and a third-floor north corridor extension continues along the south wall of Room 309.

Rooms 301, 303, 305, and 307 have coated concrete floors and gypsum board walls. They each have drop ceilings; the tiles have been removed. Many of these offices contain vertical ductwork along their walls that feature an air vent. The walls in these offices contain electrical conduit (Figure 127). Rooms 301 and 303 are connected by a single-leaf entry piercing the east wall of Room 301. A single-leaf entry pierces the north wall of Room 303, accessing the change room facilities on the third floor of the circa 1957 Change House addition (see Figure 125).

Room 309, the main Control Room, features a coated concrete floor and an exposed corrugated metal ceiling featuring exposed steel beams. The ceiling supports ductwork and a small crane. The walls are dominated by numerous control panels, electrical equipment, dials, gauges, and television screens. An L-shaped control desk is located in the center of the room. The west wall is pierced by a single-leaf entry accessing the third-floor north corridor. The south wall is also pierced by a single-leaf entry accessing the third-floor north corridor extension and contains a set of three windows overlooking the high bay (Figure 128). Beyond the control panels on the east side of the Control Room, an air lock occupies the southeast corner of Room 309 and provides access to the single-leaf exterior entry on the east elevation that accesses the north fire escape that pierces the east wall. An air-conditioning equipment room occupies the northeast corner, behind the eastern control panels (Figures 129 and 130).

The east portion of the third floor is entirely open to the high-bay. Ductwork is affixed to the east wall at the third-floor level (Figure 131).

The third-floor south wing moving west to east includes an elevator shaft, entries to Rooms 300 and 302 (both entries access a room that served as an office for the Reactor Chemistry Division); Room 304 (another office for the Reactor Chemistry Division); and Room 308 (an office for the Reactors Division that was divided into Rooms 306, 308, and 310 before 1968) (see Figure 125) (ORNL 1968d). A metal grated wall that previously contained a door is located at the west end of the third-floor south corridor. A total of four single-leaf entries pierce the south wall of the third-floor south corridor; the corridor terminates at its east end at a single-leaf entry accessing the north portion of Room 308.

The floors of Rooms 300 and 302 are linoleum tile and the walls are gypsum board. Large metal boxes are suspended from the ceiling of both rooms (Figure 132).

Rooms 304 and 308 exhibit a coated concrete floor, an exposed corrugated metal ceiling, and exposed vertical beams along the gypsum board walls. In Room 308 the framing from a former drop ceiling remains. Pipes, linear fluorescent light fixtures, and electrical conduit suspend from the ceilings. The wall between Rooms 304 and 308 is presently removed. Room 308 is irregularly shaped and features a rectangular curb in emanating from the south wall (Figure 133).

West of the reactor structure, a pair of hot cells are suspended above the westernmost pool of the reactor structure. The pools were capped with concrete shielding blocks circa 2015. The hot cells back up to one another, sharing a rear wall. The hot cells are comprised of 3 ft thick concrete and each of the four corners are flattened to provide space for an HB facility (Hamrick and Swanks 1968:47). The face of each hot cell (the north elevation for the north hot cell and the south elevation for the south hot cell) feature viewing windows, manipulator arms, and utility piping. The west elevation of the hot cell structure contains two access doors (one for each hot cell), a fuse box, and utility piping. The roof of the hot cell structure connects to a platform on the south side of Building 3042, accessible by a crane access ladder exhibiting a round safety cage that is affixed to the west wall (Figures 134–136). Southwest of the reactor structure, a semi-hot storage platform occupies the third level of Building 3042 (see Figure 134). Southeast of the reactor structure is entirely open to the high-bay.

In 1957, a three-story Change House addition was constructed at the northwest corner of the building, the second and third floors of which functioned as a men's change-room facility, containing lockers, showers, and restroom facilities; a doorway connected the change room to Room 303 on the third floor, along the north wall of the north wing (Figure 137) (ORNL n.d.e). A single-leaf entry also accesses the third floor change facilities from the walkway in the northwest corner of the third floor of the south wing in Building 3042 (see Figure 105). The materials and layout of the change facilities on the third floor of the 1957 Change House addition are nearly identical to the layout of that on the second floor (see Figures 122–124).

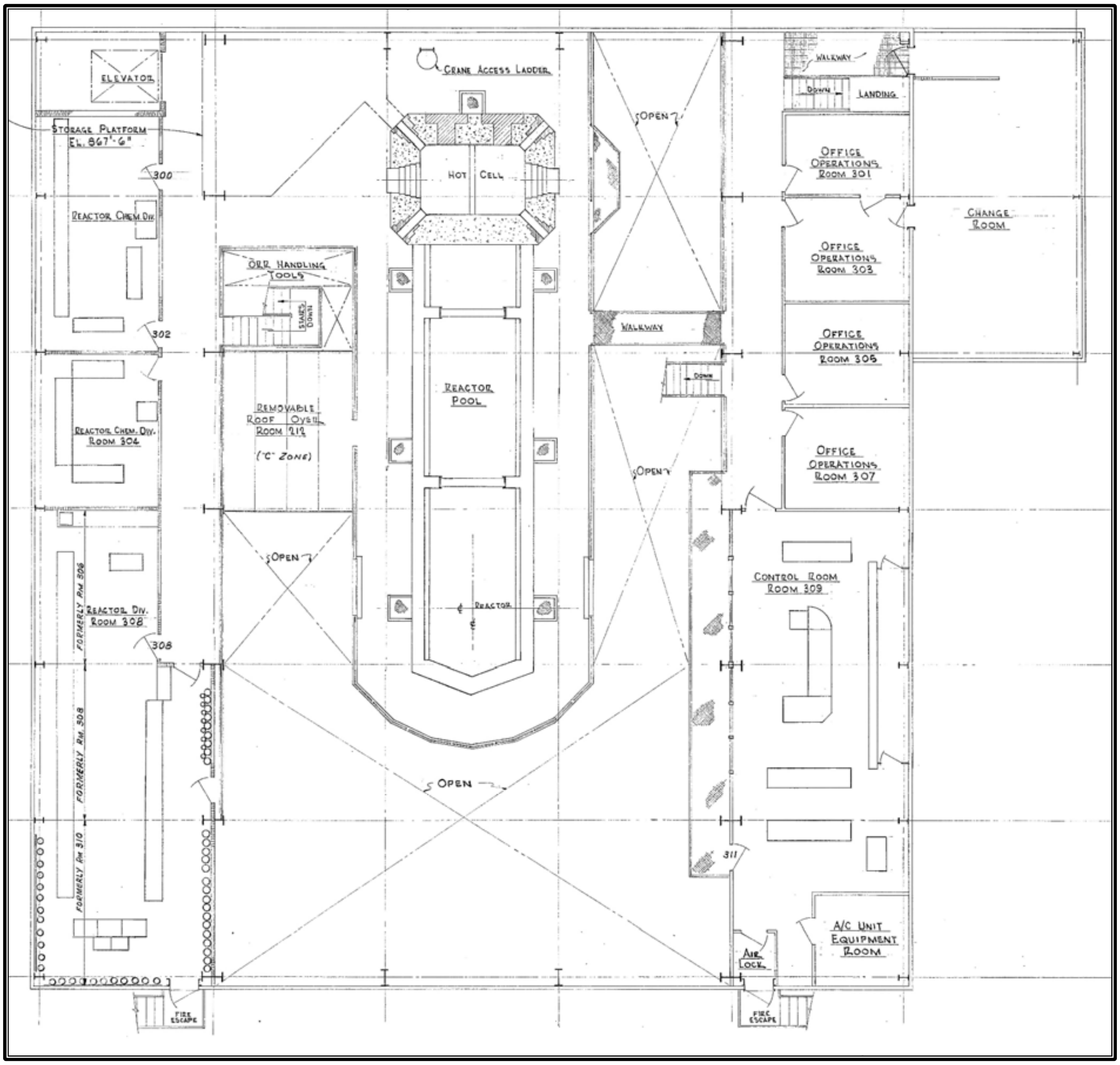


Figure 125. Portion of architectural drawing showing the floor plan of the third floor in Building 3042, issued 1968 (ORNL 1968d).

Figure 126. Current photograph showing the metal grate wall situated at the west end of the third-floor north corridor, facing east.

Figure 127. Current photograph showing an example of an office on the third floor of the south wing in Building 3042.

Figure 128. Current photograph showing the west portion of the south wall in Room 309, the Control Room, facing west toward the third-floor north corridor.

Figure 129. Archival photograph showing the Control Room, or Room 309, in the third-floor north wing of Building 3042, circa 1962 (ORNL Photo 59471).

Figure 130. Current photograph showing the Control Room, or Room 309, in the third-floor north wing of Building 3042, facing northeast. At right, the single-leaf entry leads to the northern fire escape on the east elevation.

Figure 131. Current photograph showing the east portion of the third floor in Building 3042, facing southeast.

Figure 132. Current photograph showing Room 302 in the south wing of the third floor of Building 3042.

Figure 133. Current photograph showing Room 308 on the third floor of the south wing in Building 3042, facing southwest. At right the single-leaf entry accesses the third-floor south corridor.

Figure 134. Current photograph showing the hot cell structure located at the west end of the reactor structure in Building 3042, facing northwest. The concrete shielding blocks are at right; the semi-hot storage platform is at left; and the crane access ladder and platform are at top left. The hot cell face shown is of the south hot cell.

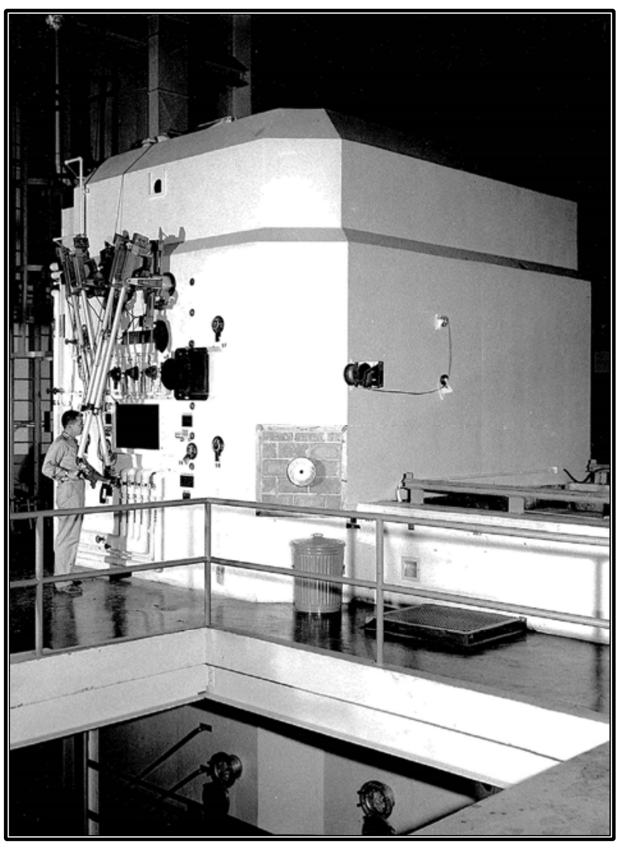


Figure 135. Archival photograph showing the South Hot Cell in Building 3042 at the ORR after completion, circa 1958 (ORNL Photo 44781).

Figure 136. Current photograph showing the west elevation of the hot cell structure located at the west end of the reactor structure in Building 3042, facing northeast.

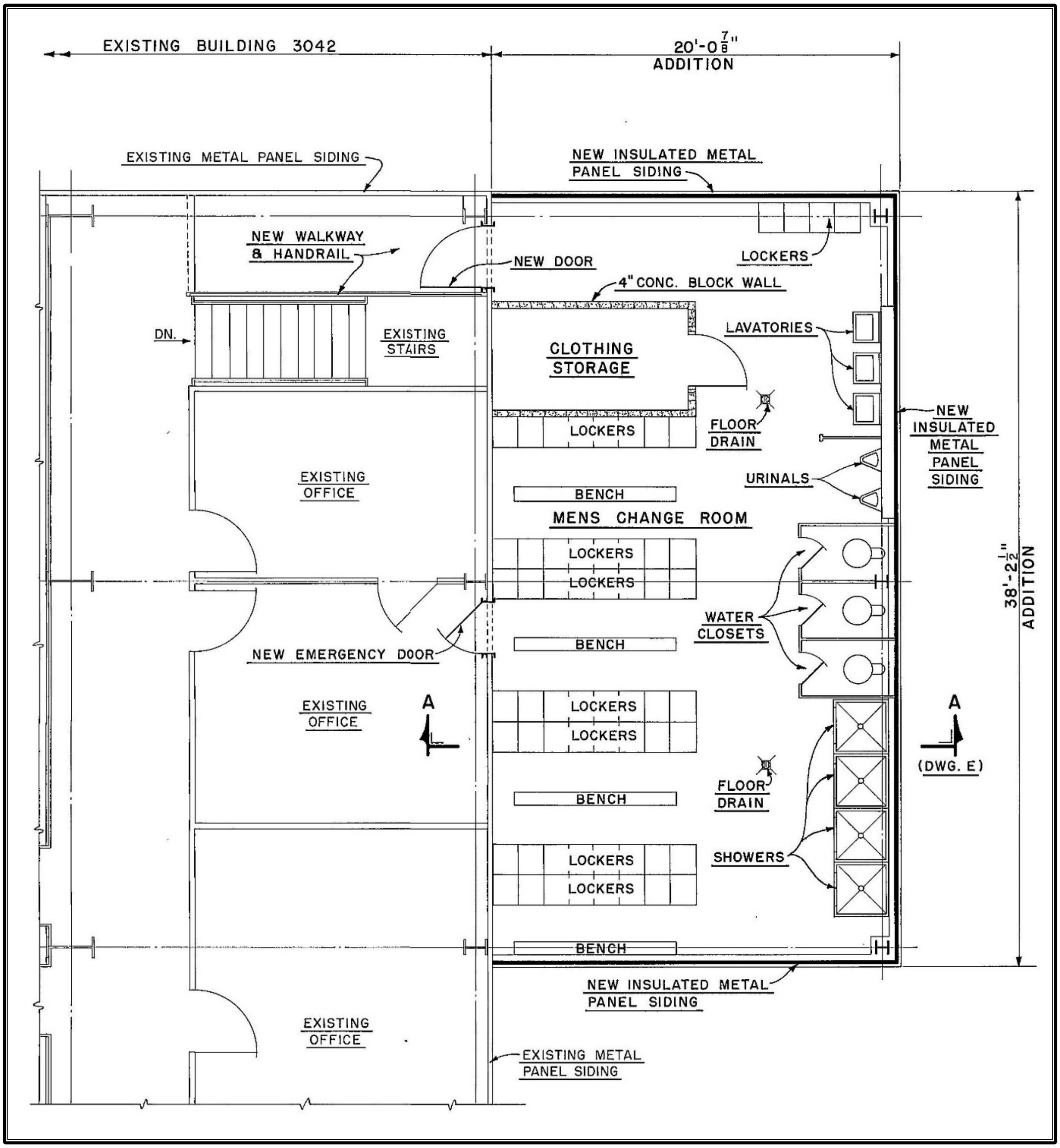


Figure 137. Architectural drawing (C-28306) showing the layout of the third floor of the 1957 Change House addition to Building 3042 (ORNL n.d.e).

Reactor Structure

At the heart of the building was the ORR reactor structure, which was the first such facility to merge features of a low-power pool reactor and a high-power tank reactor (Tabor and Costner 1962:1). A primary goal of the reactor's design was to provide easy access to the core, with the control-rod drives placed beneath the reactor and water used as the main shielding material (Hamrick and Swanks 1968:2).

Accessing the reactor for experiments was accomplished via ports on multiple sides, as well as through the top since the reactor was submerged in an open pool. With no need for an upper grid plate on the reactor, thanks to the pool arrangement, and with the control-rod drive mechanisms situated beneath the core, refueling the reactor and rearranging reactor elements was a simple process, and experiments could be left in place during refueling (Cox 1959:1). The water in the pool functioned as radiation shielding as well, in addition to the thick barytes concrete wall of the reactor structure.

The reactor core was arranged in a seven-by-nine rectangular lattice of 63 spaces, which contained the fuel elements, shim (control) rods, beryllium reflector pieces, and experiment pieces (Figure 138) (Tabor and Costner 1962:2, 14). The core was situated near the bottom of a reactor vessel made of aluminum, approximately 15 ft tall and 5 ft in diameter (Figure 139) (Cole and Gill 1957:8). The tank in turn was positioned within the easternmost of three rectangular pools made of reinforced barytes concrete lined with one-quarter-inch thick aluminum plate welded to an aluminum structure embedded in the concrete, filled with demineralized water (Tabor and Costner 1962:2; Wright 1956:22). The three pools, with a total capacity of about 150,000 gallons, were each approximately the same size, 20 ft long and 10 ft wide, consisting 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, respectively, all separated from each other by water-tight aluminum and steel gates (Figures 140–142) (Cole and Gill 1957:10, 11, 12; Tabor and Costner 1962:2). Within the three pools were racks for storing partially depleted elements (Tabor and Costner 1962:15). By having two storage pools, where fuel elements, irradiated equipment, and certain experiments could be placed, one storage tank could be emptied and cleaned at a time (Wright 1956:21). Around the top of the reactor structure was a parapet wall 3 ft high and 18 inches thick, and a 7 ft wide concrete walkway (Figure 143). 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. At the ceiling, spanning the 60 ft width of the high bay, was a 20-ton bridge crane with a 1-ton auxiliary hoist.

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 (Wright 1956:24). Experimental facilities around the perimeter of the reactor structure included six beam holes 6 inches in diameter along the semi-dodecagonal eastern end, used primarily for semi-permanent experiments involving the irradiation of small samples, and two large ports on the north and south sides known as the North and South Engineering Test Facilities, approximately 19 inches by 25 inches, for more substantial engineering experiments pertaining to reactor fuel research (Figures 144–146) (Cole and Gill 1957:1, 24, 43).

Two hot cells were completed in 1958 at the west end of the reactor at the third-floor level and are discussed above. Over the years, ORNL added other equipment and experiment spaces to the north and south sides of the reactor structure. Substantial programs led to the construction of rooms and cells which are also discussed above according to floor location.

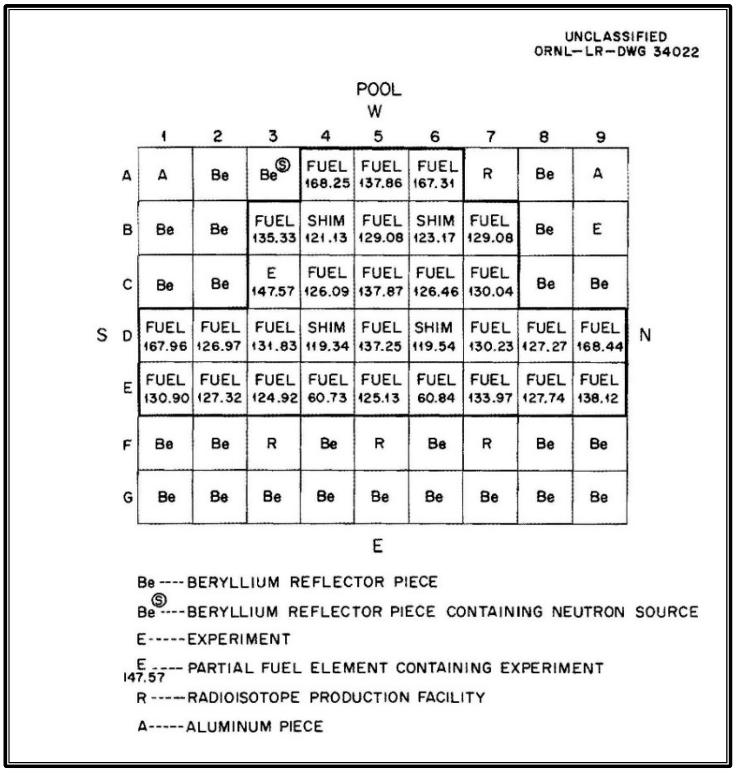


Figure 138. Configuration of the ORR reactor core, including legend (Tabor and Costner 1962:14).

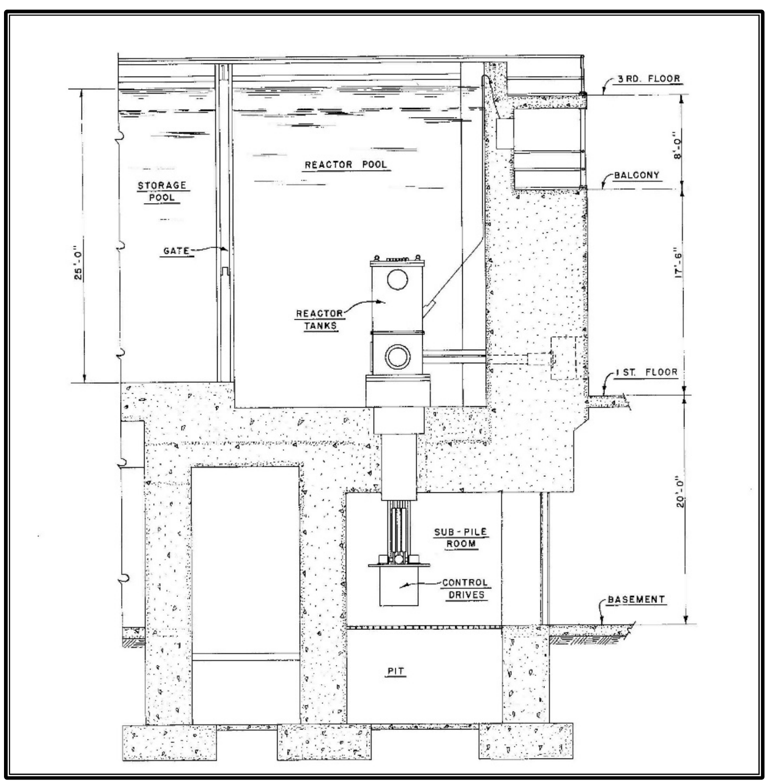


Figure 139. Vertical cross-section drawing of the ORR reactor pool and sub-pile room in Building 3042 (Cole and Gill 1957:8).

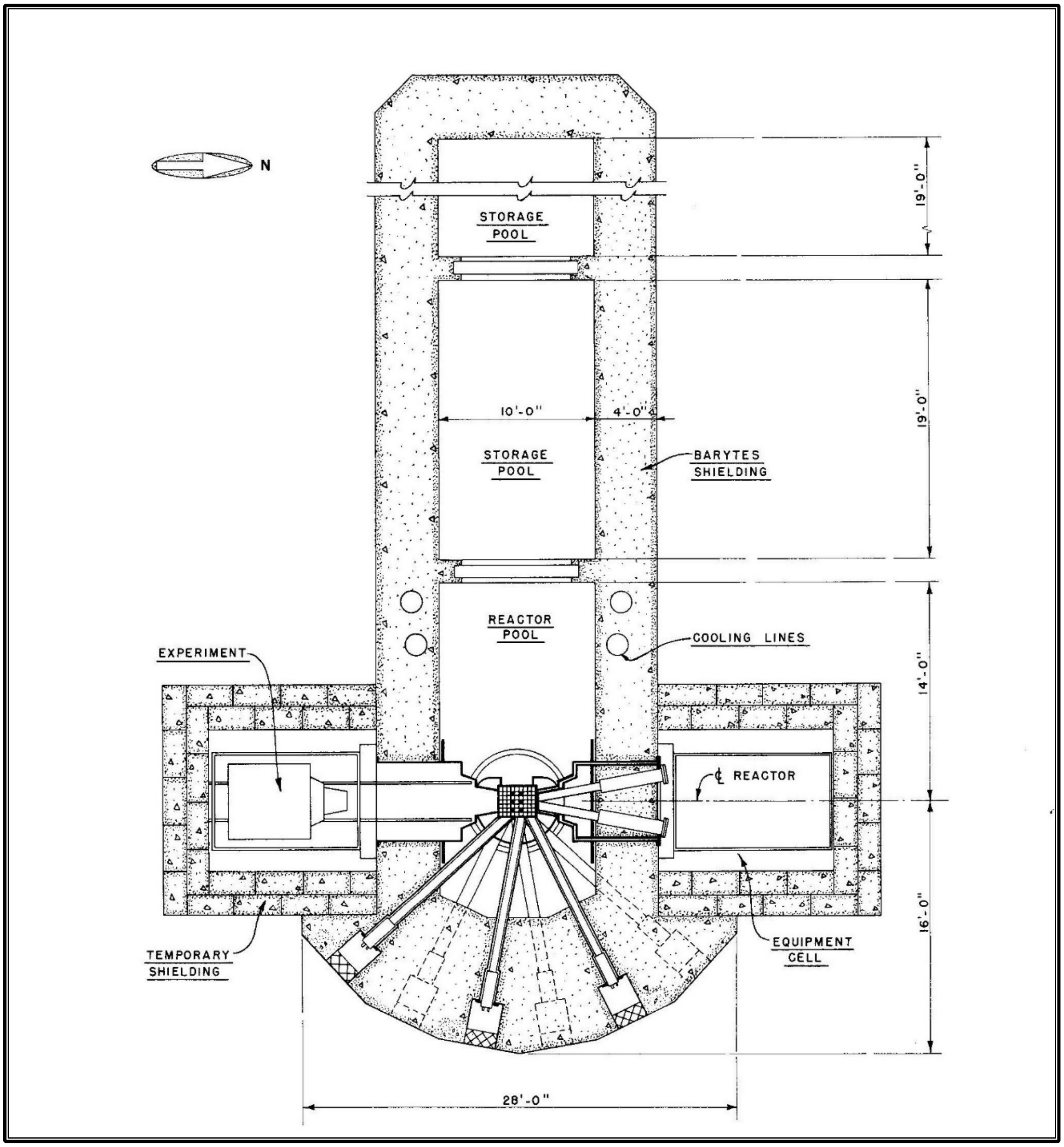


Figure 140. Overhead drawing of the ORR reactor structure in Building 3042 (Cole and Gill 1957:10).

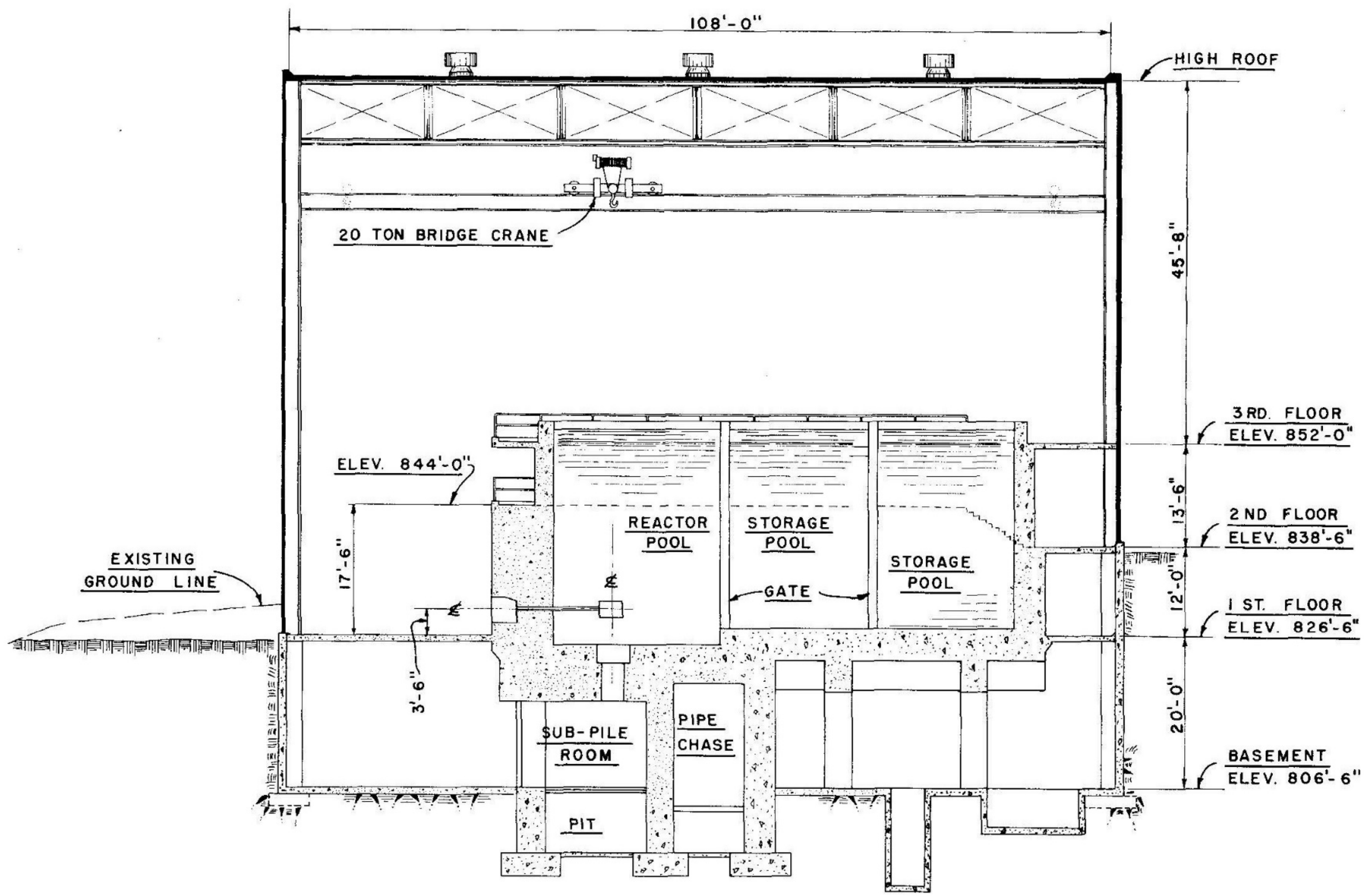


Figure 141. Cross-section drawing of the ORR reactor structure in Building 3042 (Cole and Gill 1957:11).

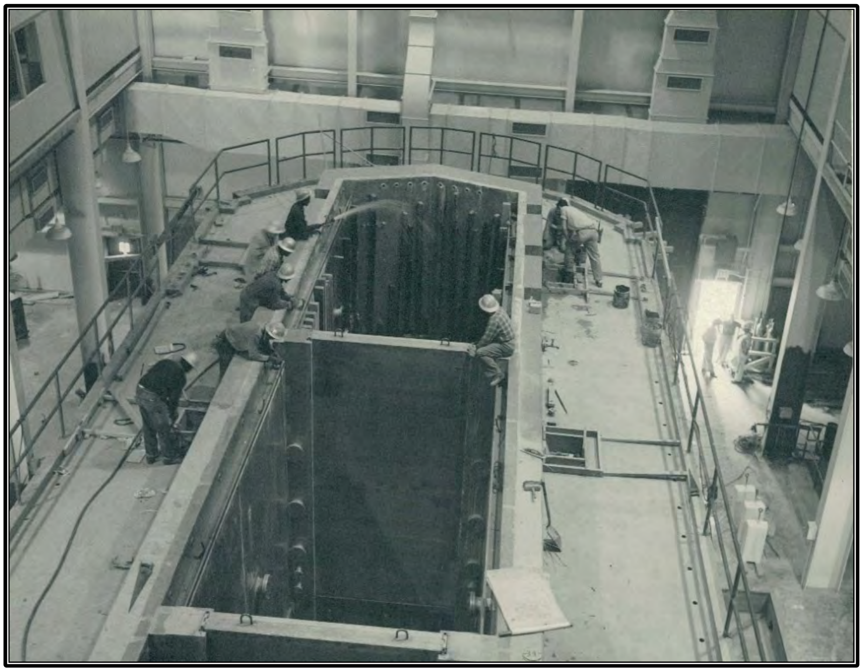


Figure 142. Archival photograph of the construction of Building 3042 showing the three pools in the reactor structure, 1957 (ORNL Photo 57-0488).

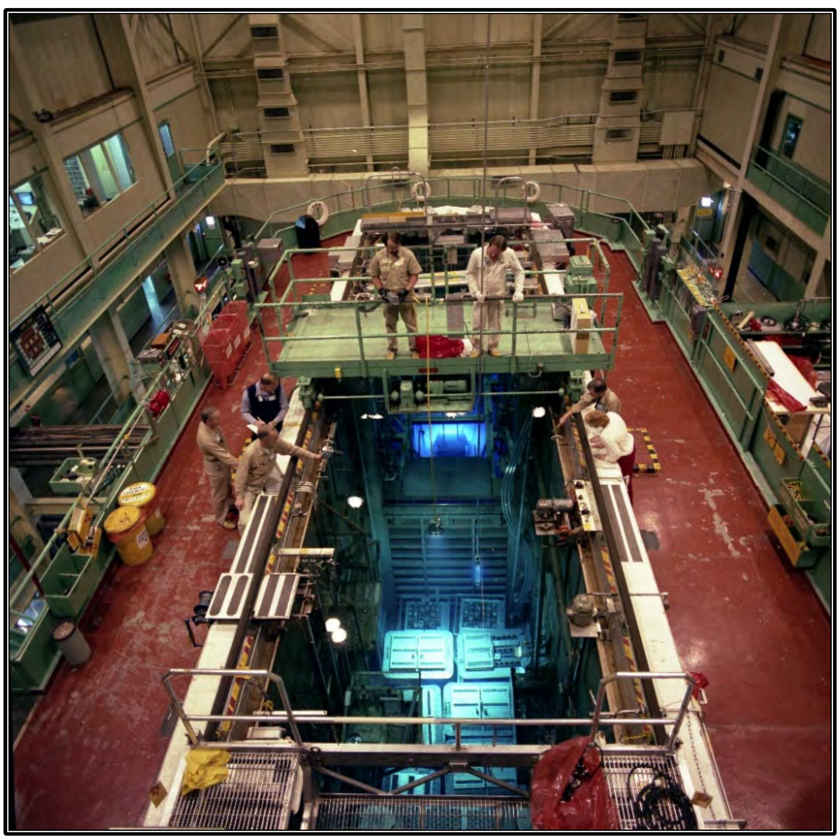


Figure 143. Archival photograph looking down on the reactor structure in Building 3042, showing the parapet wall, the perimeter walkway, and a storage pool, circa 1983. Two employees stand on the walk bridge across the reactor pool and the reactor pool emanates a blue glow due to the Cerenkov effect (ORNL Photo 08104-83).

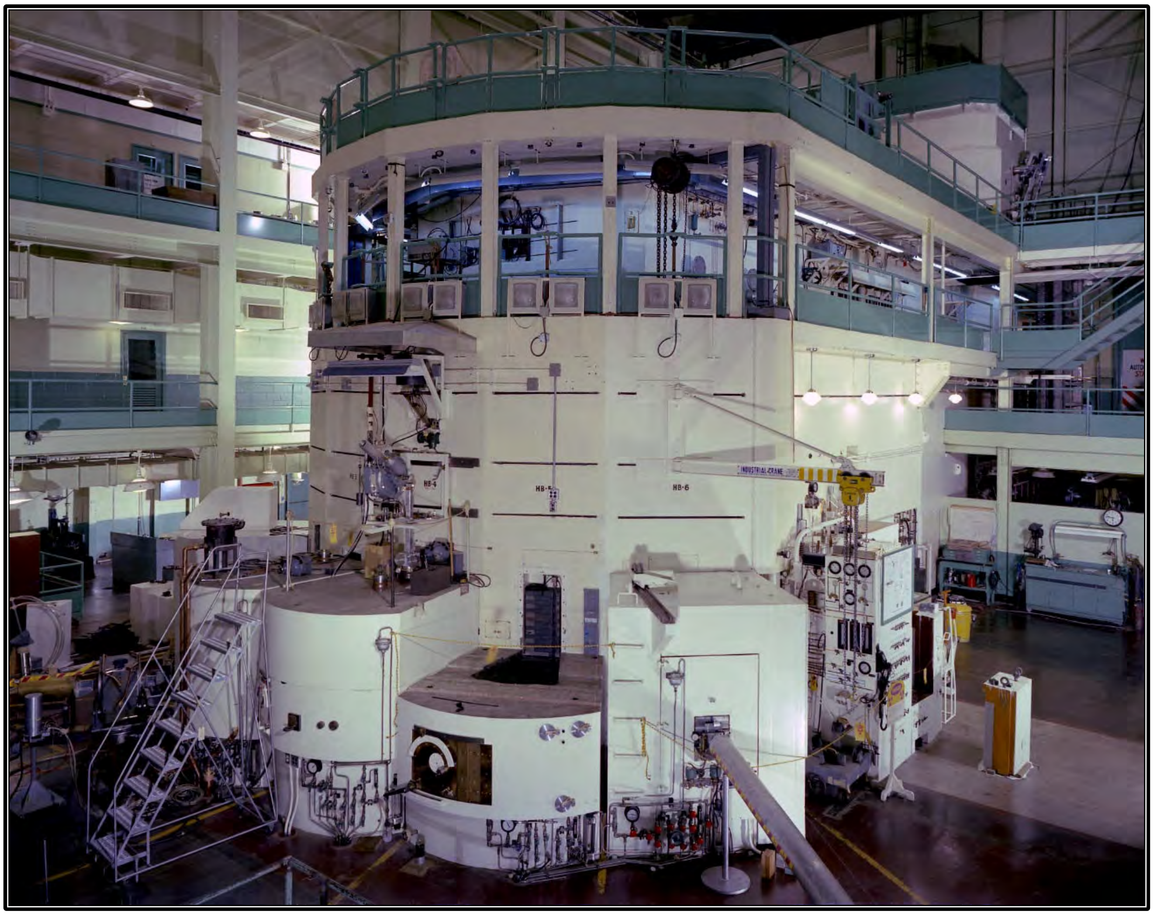


Figure 144. Archival photograph of the interior of Building 3042 showing multiple experiments utilizing the beam holes at the base of the reactor structure, 1960 (ORNL Photo 48863).

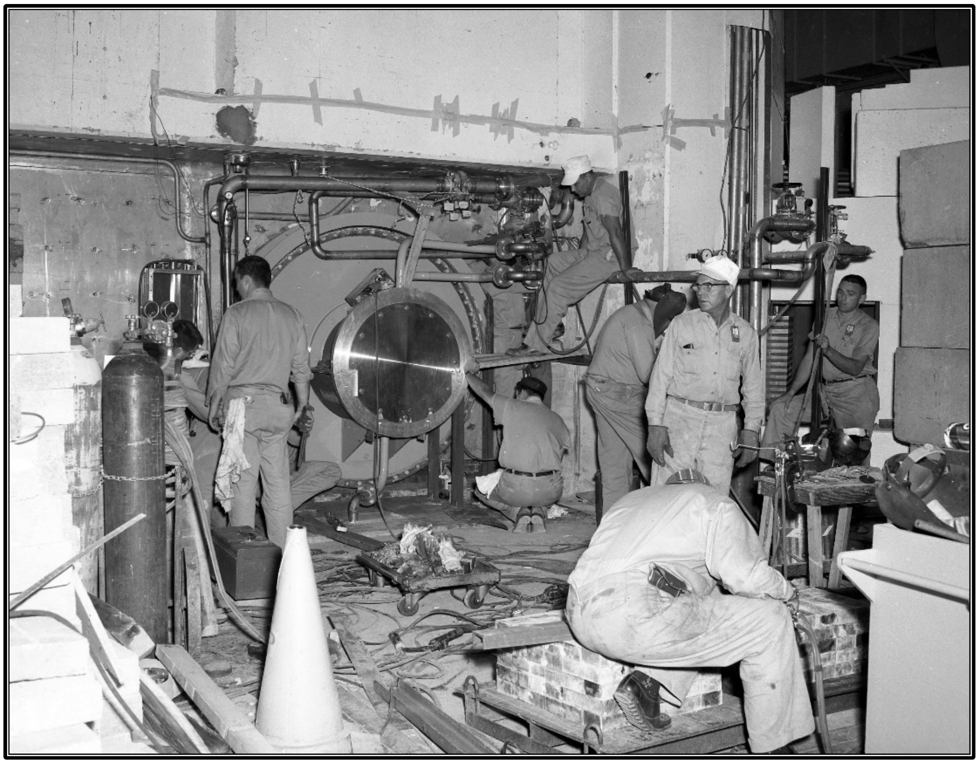


Figure 145. Archival photograph of the interior of Building 3042 showing installation of equipment at one of two Engineering Test Facilities on the reactor structure, 1960 (ORNL Photo 51474).

Figure 146. Current photograph showing one two Engineering Test Facilities on the reactor structure.

HISTORY OF BUILDING 3042

ORNL commenced its long history with reactor design, construction, and research in 1943 with the construction of Clinton Laboratories and the Graphite Reactor, frequently referred to as the X-10 pile or uranium-chain reactor, during World War II (see Figures 4 and 5) (Rogers 2018:2). This remained the only reactor operating at Oak Ridge throughout the war. After the war, the AEC sought a division of research responsibilities across their multiple National Laboratories. They hoped that by considering what each laboratory was most qualified for, they would avoid redundancy and consolidate resources to achieve research goals most efficiently across the Commission's facilities. The AEC officially announced in December of 1947 that reactor development activities would be focused at the ANL while Clinton National Laboratory (previously Clinton Laboratories) would be utilized for basic research, particularly in applied chemistry and isotope production. This directive indicated that many of the established personnel at Clinton National Laboratory, and their research, would be transferred to ANL. This research included the development of plans for the design of a theoretical high-neutron-flux reactor, "a reactor which would produce a high concentration of neutrons—the type known as a high-neutron-flux reactor" (Thompson 1952:10; Smith et al. 1951:8).

Predecessors to the ORR

Having worked with the Graphite Reactor during the war to produce radioisotopes intermittently, many of which were in use for medical research as early as 1946, researchers at Clinton Laboratories, which later became ORNL, were aware of the multitude of benefits awaiting to be harnessed from the advancement of nuclear reactor design. In the years following the end of World War II, Clinton Laboratories scientists eagerly anticipated further researching the myriad of opportunities the burgeoning field of nuclear science might provide beyond the atomic bomb. Waldo Cohn, a biochemist employed at ORNL during and after the war, believed: "discovering how radiation does what it does to inorganic, organic, and living matter will benefit the entire world" (Johnson and Schaffer 1992c:58). Many scientists, including many of those at Clinton Laboratories, vied for the opportunity to contribute to the design and execution of a high-flux experimental reactor, which carried with it the potential for groundbreaking scientific discoveries. Clinton Laboratories staff began developing plans for a theoretical high-neutron-flux reactor in 1946 and drafted a feasibility report in 1947 (Smith et al. 1951:8; Thompson 1952:10).

ANL, selected by the AEC to lead reactor development activities, was already stretched thin in the late 1940s. As a result, their administration supported Clinton Laboratories interest in continuing the design and fabrication of the high-neutron-flux reactor that would come to be known as the MTR. Sensing an opportunity, Clinton Laboratories urged the AEC to consider constructing the MTR on the Cumberland Plateau, several miles outside of Oak Ridge (Johnson and Schaffer 1992c:64). In 1948, however, the AEC selected Arco, Idaho as the site for the construction of this much anticipated high-flux experimental reactor, due to the remoteness of the location. They named this new reactor the MTR: "an important advance will soon be made in the study of radiation damage with the installation at Arco of the Materials Testing Reactor. This reactor and its associated experimental facilities are specifically designed to study the behavior of materials in a high flux of radiation" (Lansing 1951:280).

In the midst of these shifting plans, Carbide and Carbon Chemicals Company became the operating contractor at Clinton National Laboratories and the name of the site was changed to ORNL on March 1, 1948 (Thompson 1963:57-62). In November 1948, the AEC organized a MTR Steering Committee including personnel from both ORNL and ANL. They determined that ORNL would complete the final reactor design and ANL would design the reactor building and ancillary facilities. The only reactor development activities at ORNL in 1948 were designing the MTR to be constructed in Idaho at the new National Reactor Testing Station. Using the 1947 feasibility report as a guide, ORNL "constructed a full-scale model of the reactor to test certain phases of the design" (Thompson 1952:10; Smith et al. 1951:8). This required ORNL to build a full-scale mockup, including the reactor tank and core components, in order to test the hydraulics, mechanics, and cooling systems (Figure 147). Eugene Wigner, a chemical engineer and physicist, served as the Director for Research and Development at ORNL in the late 1940s. He led research reactor development at that time, including the design of the MTR. Due to the nature of the design experimentation, the MTR mockup exhibited all the characteristics required for an operating reactor. In 1949, the hydraulic tests of the MTR mockup were successfully completed and talk of plans for criticality experiments circulated (Cagle and Casto 1968:1-1–1-4).

Alvin Weinberg, who became the Director of Research at ORNL after Wigner in 1949, proposed installing uranium fuel plates in order to test the MTR design under critical conditions. He explicitly stated to the AEC at that time that he had "no plans … to convert the critical experiment into a reactor" (Johnson and Schaffer 1992c:64). The AEC authorized ORNL to perform critical experiments to ensure proper reactor performance. These experiments were executed in 1950 and low-power measurements were made that influenced the final MTR design (Cagle and Casto 1968:1-1–1-4). Despite Weinberg's previous assurance to the contrary, ORNL later requested permission to install shielding and utilize the MTR mockup as a research reactor. Weinberg was often accused of trying to maintain reactor research technology programs at ORNL, against the 1947 AEC directive. In a 2003 interview, Weinberg stated "with respect to the centralization of [research on] reactors, I just didn't believe that was possible… I did all I could to keep Oak Ridge in the reactor business" (Weinberg 2003:6).

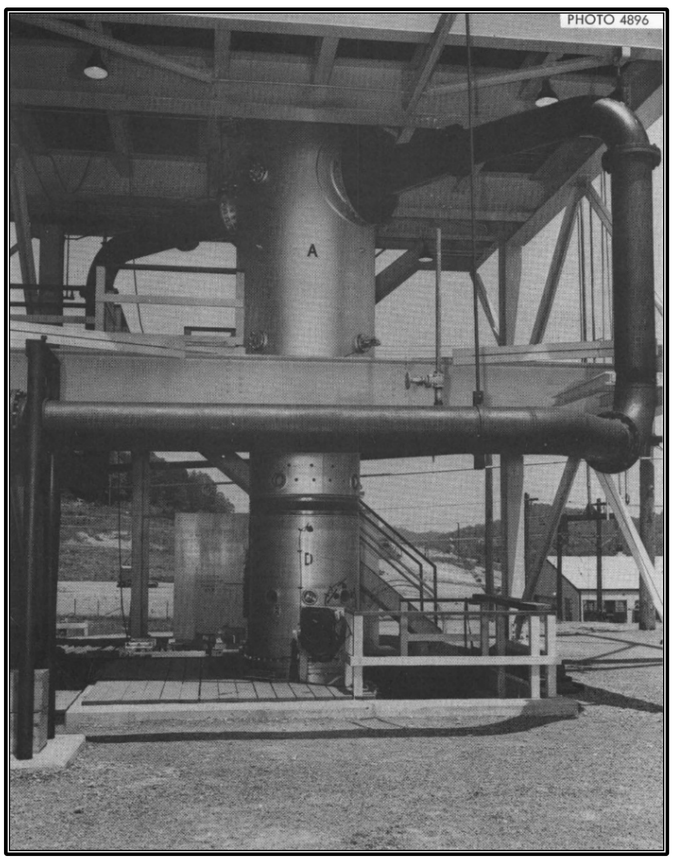


Figure 147. Archival photograph of the hydraulic mockup of the MTR showing the structural metal framing built around the reactor and the majority of the reactor tank before it was surrounded by shielding and converted to the LITR, circa pre-1950 (ORNL Photo 4896) (Cagle and Casto 1968:5-16).

The AEC, easing their previous plans of reactor development centralization at ANL, ultimately approved the utilization of the MTR mockup as a research reactor at ORNL in 1949, with power levels up to 1,000 kw, equivalent to 1 Mw (Thompson 1963:66-67). Critical experiments commenced in January 1950, and criticality was reached on February 2 (Mann and Lane 1950:7). By March 2, 1951, ORNL successfully converted the MTR mock-up to the 500 kw LITR and by the end of that year they increased the LITR power level to 1 Mw, considered to be "normal" (Cagle and Casto 1968:1-1–1-4). Sam Beall, an employee at ORNL starting in 1943 involved in early reactor development, recalled:

> *The reactor design at that time under Jim Lane and Alvin Weinberg was for the Materials Testing Reactor. We had a lot of tests going on fuel rods and fuel elements. They asked us to make a mockup of the MTR with a full-size tank and full-size flow. We assembled that thing and did the testing. When all that was done, Alvin called me in and said, 'We have some fuel elements that Marvin Mann and Walter Jordan have used to do criticality experiments. You have been testing control rods and the metallurgists have beryllium blocks that are supposed to go into a reflector [to reflect neutrons back into the reactor core to help sustain the core's fission reactions]. Can you make a reactor out of that?'... A technician named J. J. Harrison and I were tasked to put this all together. We didn't have any money, but we put concrete blocks around the reflector and poured tons of sand in the space between the blocks and the tank. We were ready to make the MTR assembly go critical in February of 1950. We were so nervous because there had never been a reactor fueled with enriched uranium go critical before. Just as we were ready to go critical after counting the neutron flow rate, this technician, who was a wag, blew up a paper bag and popped it like that. Everybody went to pieces. I almost fired him for that* [Beall and Haubenreich 2003:4].

ORNL named this reactor the Low-Intensity Training Reactor in late 1950, generating the initials LITR that would remain after it was renamed the Low-Intensity Testing Reactor in 1952 (Cagle and Casto 1968:1-1). The LITR, housed in Building 3005, thusly became the second reactor constructed at ORNL (Figures 148 and 149).

Meanwhile, in Idaho, the Fluor Corporation out of Los Angeles served as the contractor for constructing the MTR at the Reactor Testing Station, with an estimated cost of approximately 18 million dollars. ORNL constructed the core in consultation with ANL. The MTR would operate "in the thermal, or slow, neutron energy range" in order to "give research workers a much-needed tool—a reactor in which to test materials under a neutron bombardment more intense than is produced in any other known reactor" (Murray et al. 1950:167). The MTR Steering Committee and Idaho Operations Office agreed in January 1950 that ORNL would be responsible for the fabrication, inspection, testing, and, ultimately, shipping the reactor tank and its contents to Idaho, rather than hiring a subcontractor. The installation of the MTR in Idaho was scheduled to be completed by April 15, 1951 (Figures 150 and 151) (Mann and Lane 1950:6–7, 23).

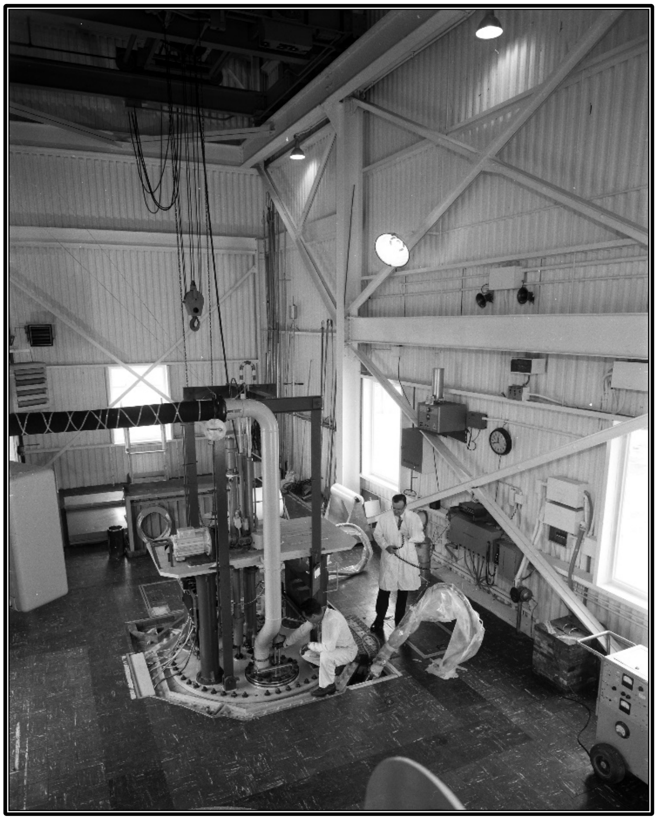


Figure 148. Archival photograph of Building 3005 interior, showing employees working with the LITR on the third floor, circa 1967 (ORNL Photo 86488r).

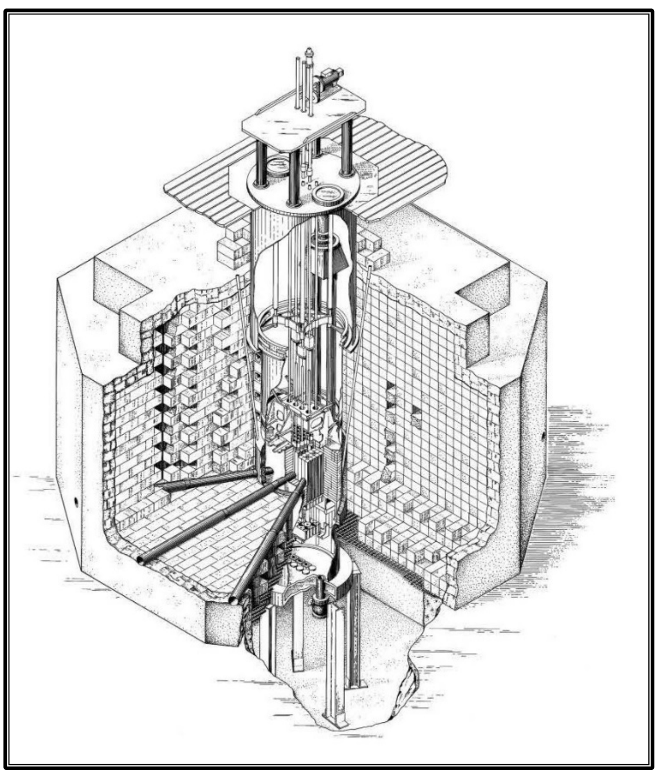


Figure 149. ORNL Drawing (ORNL-LR-DWG 11485) of a cutaway view of the LITR, undated (Rosenthal 2010:42).

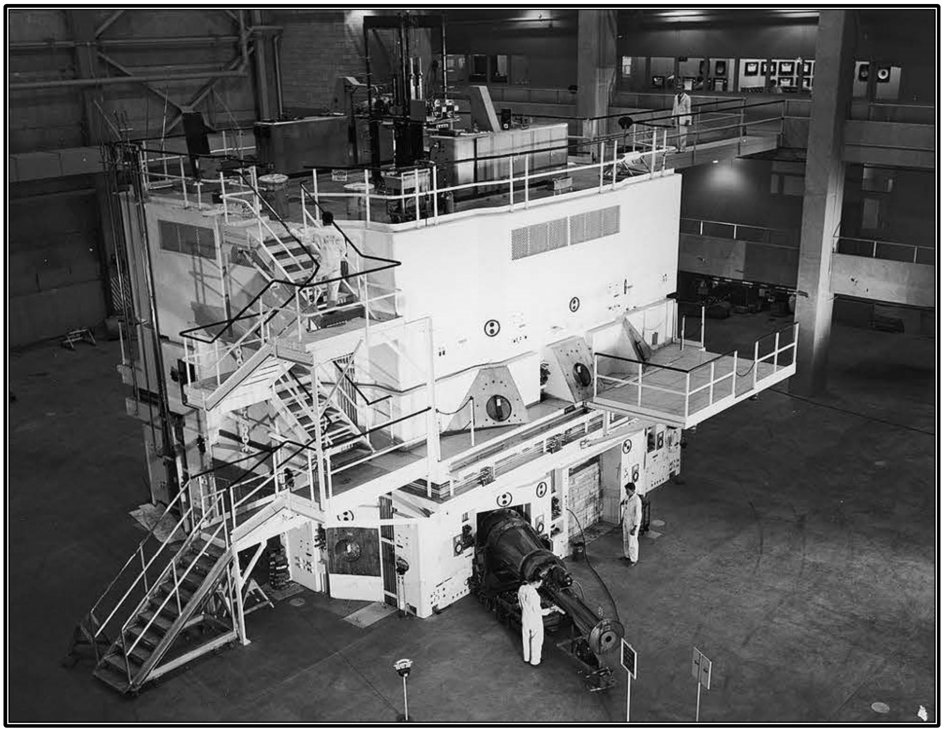


Figure 150. Archival photograph of the MTR in operation at the National Reactor Testing Station, now the Idaho National Laboratory, undated (Rosenthal 2010:41; courtesy of Idaho National Laboratory).

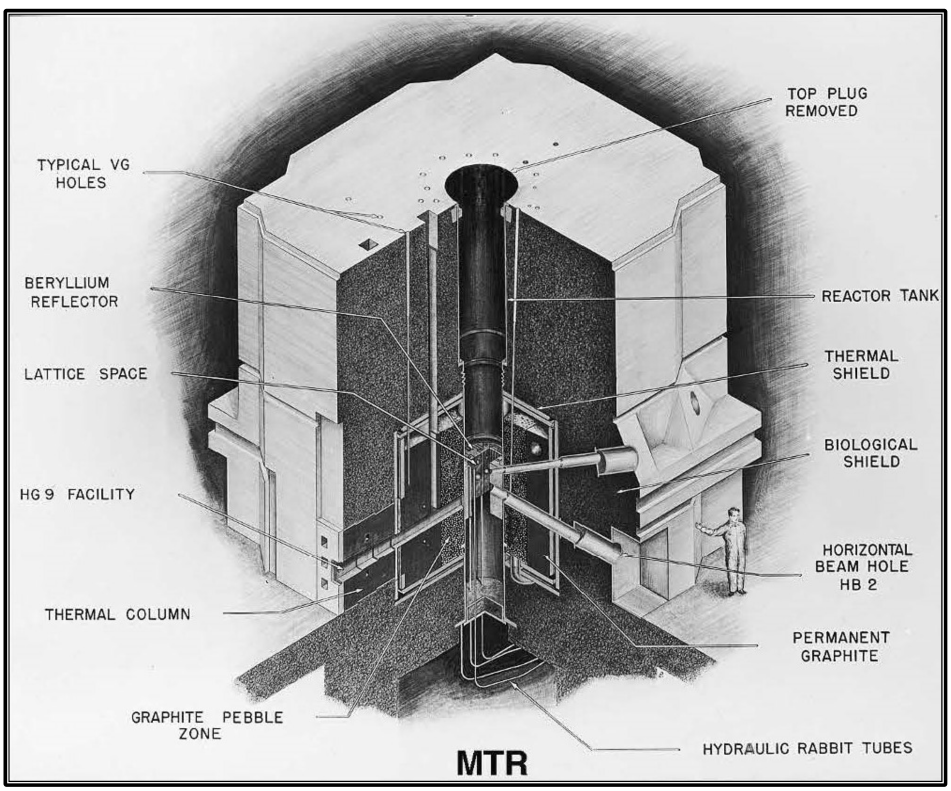


Figure 151. Drawing of a cutaway view of the MTR (Rosenthal 2010:31; courtesy of Idaho National Laboratory).

The MTR and LITR pioneered water-cooled reactor development. Those in charge of the overall AEC reactor designing program confronted the objective of deciding what reactor designs to focus on: "there are an enormous number of possible reactor designs. There are so many designs that one cannot expect to get enough money from the U. S. Government to exploit all" (Lansing 1951:36). The MTR design was amongst the first group of reactors to be selected for funding and construction due to its potentially balanced program, contributions to the military mobile reactor projects, production of fissionable materials, and promise of future civilian power (Lansing 1951:36-37). This design became so successful that it led to not only the LITR at ORNL, but the BSR and the ORR, not to mention countless other water-cooled and moderated research reactors around the world. Murray Rosenthal, who came to ORNL in 1953 to work with reactors, stated in a 2009 interview: "The Materials Test Reactor [sic] was followed by the aqueous homogeneous reactor aimed at breeder reactors that would generate more fuel than they consumed. Next, the Laboratory got into developing a reactor to use on nuclear powered airplanes… [the MTR] turned out to be very important because off shoots of it were built around the reactor to use in research programs. The HFIR reactor, its most advanced descendent is still used at the Laboratory today" (Rosenthal 2012:16-17). At the time of its construction, the LITR provided the highest neutron flux available at ORNL. Economics and efficiency propelled the popularity of water-moderated reactors as many other experimental designs, such as the breeder reactors, were inordinately expensive to build. As ORNL thoroughly explored the multitude of reactor design options throughout the 1950s, Melvin Tobias, of the Reactor Experimental Engineering Division, recalled management encouraging his Division: "Well, fellas, stick with those water reactors. We can't beat them" (Tobias 2017:34).

As a result of the ongoing ANP Project, discussed further below in "The ANP Project" section, on December 21, 1949 ORNL submitted an initial proposal to the AEC to construct a low-power reactor operating within a pool of water, providing the flexibility of a mobile reactor core and, furthermore, a multitude of potential experiment locations at varying distances from the reactor core. A supplement to this request was provided February 10, 1950 (Breazeale 1951:6; Breazeale et al. 1950:8). The proposal submitted by ORNL to the AEC suggested a reactor with a maximum operating power level of 10 kw and a critical assembly comprised of MTR fuel units. The proposal further described a "low power, water cooled and moderated (partially), beryllium oxide reflected reactor [serving] as a fission source for neutron and gamma ray attenuation measurements through bulk shielding samples and through mock-ups of practical shields" (Breazeale et al. 1950:8). The BSR, housed in Building 3010 of the Bulk Shielding Facility (BSF), became the third reactor constructed at ORNL in 1951 and received its formal name as it was "immediately used to study, in bulk, various materials for use in improved radiation shields" (Thompson 1963:68). Informally, the BSR was called the "swimming pool reactor" (Figures 152 and 153).

The BSR could be utilized for multifaceted research and was therefore shared by multiple ORNL divisions throughout its history. Originally, it was constructed with the intention of conducting shielding experimentation for the ANP Division. The shield mockups would be placed into the BSF pool at varying distances from the reactor for the purpose of measuring radioactive penetration. Since the pool water supplied a controlled source of radiation, the BSF was commonly utilized for experiments in reactor physics, such as the impacts of radiation on material properties, defects induced on different materials by radiation, and fission-neutron spectra studies with various isotopes. The fission-neutron spectra studies researched the varying energies and times of release of the prompt neutrons, those "born" at the time of fission, for different elements and circumstances. These studies helped guide the details of design, control, and shielding in nuclear reactors and other nuclear fission devices. Finally, the reactor itself was studied as a prototype for other research reactors. The BSR provided an opportunity for ORNL to obtain data on reactor operations, engineering, radiation poisoning, and the many potential uses of a swimming-pool-type reactor (Blizard 1956:v).

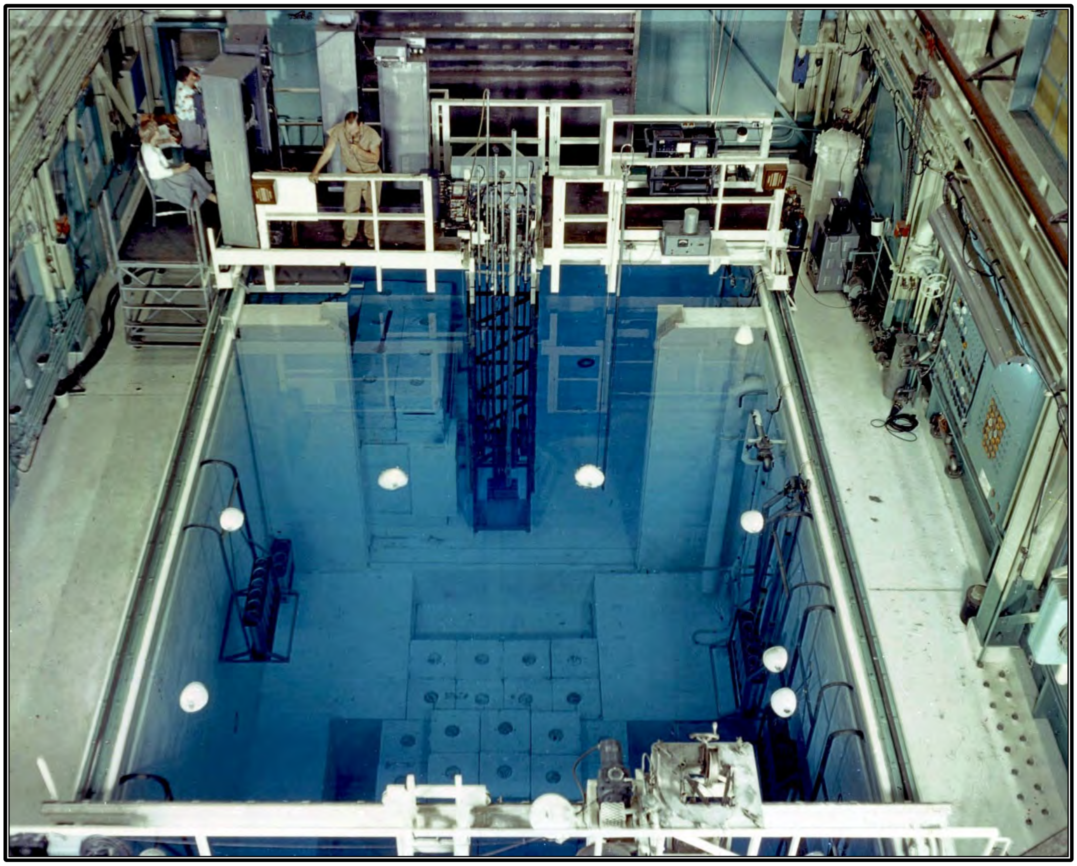


Figure 152. Archival photograph of the BSR pool in the Reactor Bay of Building 3010, circa 1957 (ORNL Photo 40047).

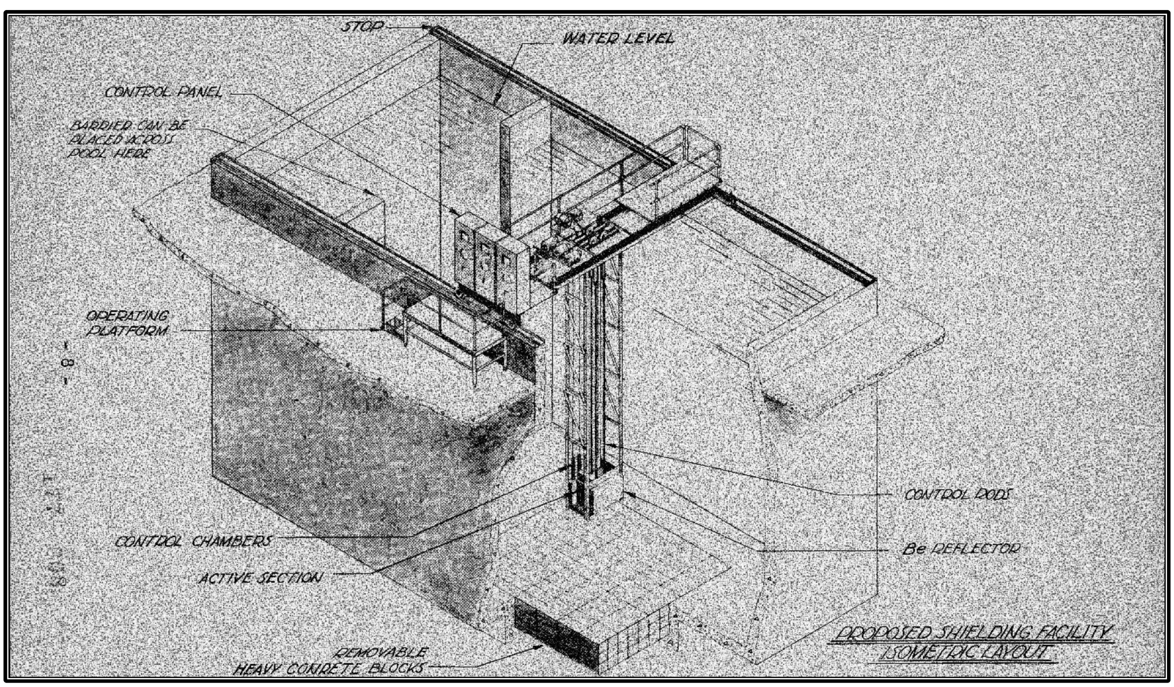


Figure 153. Original proposed drawing showing a cutaway view of the BSR pool, including location for barrier, removable blocks in inner pit, the reactor bridge, and BSR, circa 1951 (Breazeale 1951:8).

The benefit of the BSR through the 1950s was twofold. The nuclear energy field flourished after the war, however, education and training in the field were severely lacking. As the AEC nuclear operations expanded, the availability of properly trained staff was of concern. ORNL researched adapting the MTR design for the creation of an inexpensive, safe, and flexible reactor that could be used for educational purposes. This concept was actualized in the BSR. The BSR not only allowed for ORNL research, but demonstrated the feasibility of a reactor for use in nuclear education programs at universities. The successful operation of the MTR, LITR, and BSR led to the standardization of research reactor designs utilizing the "swimming pool" concept and many reactors of this type were later constructed at universities and research facilities, including the ORR at ORNL (Thompson 1963:68).

The "swimming pool" reactor design made its international debut in August of 1955, when the United Nations sponsored the first international Atoms for Peace Conference in Geneva, Switzerland. This conference included attendees from over 70 countries. The Palace of Nations displayed multiple exhibits by various governments regarding the variety of peaceful uses for atomic energy (Charpie 1955:27–32). At the suggestion of Tom Cole, ORNL proposed the United States provide an operating nuclear reactor. The AEC approved the suggestion, and within five months ORNL designed, assembled, tested, disassembled, and shipped by an Air Force plane to Geneva from Knoxville a small reactor almost replicating the design of the BSR. Due to the weaponized nature of uranium and international shipping laws, the fuel elements contained a lower enrichment than those of the BSR. This project was dubbed "Project Aquarium" and the small "swimming-pool-type" reactor it created was nicknamed the "Aquarium Reactor" (Johnson and Schaffer 1992d:106–107; Rosenthal 2010:45).

The Geneva Reactor became an international prototype for research reactors. The prototype could be fueled by low-enrichment fissionable material, the same type of fuel furnished to the international stockpile by the United States, therefore any nation could construct one utilizing an allotment of the fuel in the stockpile accumulated for the international atomic agency proposed by President Eisenhower. The U.S. contributed enough of this fuel to generate 40 to 50 research reactors. At the end of the conference, the Swiss government purchased the Aquarium Reactor for $180,000, approximately half the cost of construction, to use as a research facility at Würenlingen and named it Saphir, due to the characteristic blue glow (Figures 154 and 155) (Rosenthal 2010:45; Charpie 1955:33). Alvin Weinberg, Director of ORNL in 1955, believed ORNL's participation in the conference and contribution of the little reactor made the Laboratory "an institution of international reputation" (Johnson and Schaffer 1992d:108).

The design of the Geneva Reactor fuel assembly and fuel elements, as well as those of the BSR and ORR, stemmed from lessons learned during design investigations with the MTR Mock-up, or the LITR (Breazeale et al. 1950:8). "The MTR fuel assembly body consists of a group of 18 curved fuel plates brazed to two grooved side plates [Figure 156]. The fuel plates consist of cores of uranium-aluminum alloy clad entirely with aluminum. The side plates are also of aluminum. Later this unit is provided with suitable aluminum alloy adapters [Figure 157] which position the assemblies in the reactor core according to the upper and lower reactor grid spacings" (Smith et al. 1951:9). The curved nature of the MTR fuel plates, which later prevailed in reactor development, was the brainchild of Wigner. As recalled by Beall:

> *The [design section] specified everything, like the [water coolant] flow rate between the plates [uranium sandwiched between aluminum cladding]. [The development section] tried to show they were correct [in their calculations]. The first fuel elements at that time were plain flat plates [arranged in parallel with spaces between them to allow flow of the water coolant]. When we were testing them, the differences in the water flow caused the plates to bend either right or left and dangerously close to the next one [so that coolant flow could be restricted, causing dangerous overheating of the fuel]. Wigner suggested, 'Why don't we all bend them in the same direction [for structural resistance] to begin with?' So, the Materials Testing Reactor turned out to have curved fuel plates* [Beall and Haubenreich 2003:5].

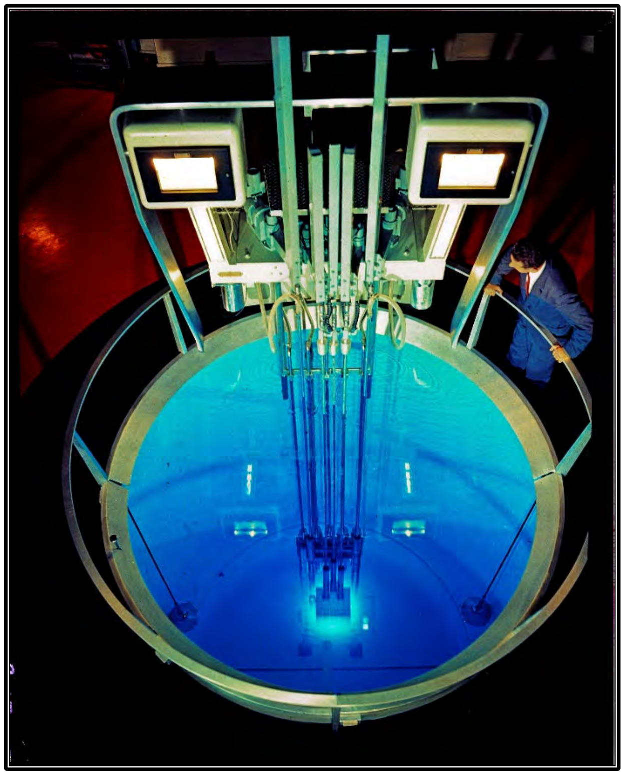


Figure 154. Archival photograph of the Geneva Reactor exhibit installed at the Palace of Nations in Geneva, Switzerland circa 1955 (ORNL Photo 17105) (Rosenthal 2010:46).

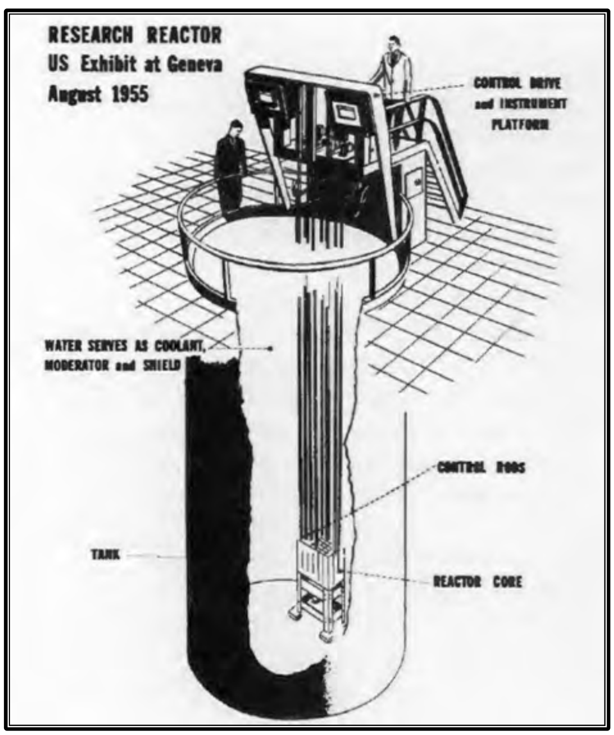


Figure 155. Drawing of the research reactor designed for the Atoms for Peace Conference in Geneva, Switzerland in 1955 showing the control drive, instrument platform, tank, control rods, and reactor core (Johnson and Schaffer 1992d:106).

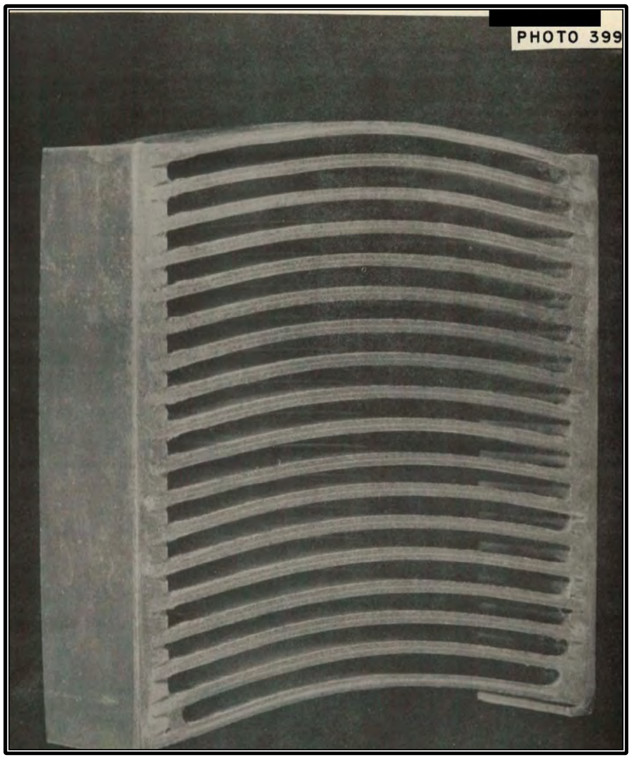


Figure 156. Archival photograph of the MTR fuel element assembly cross section (ORNL Photo 3999) (Smith et al. 1951:10).

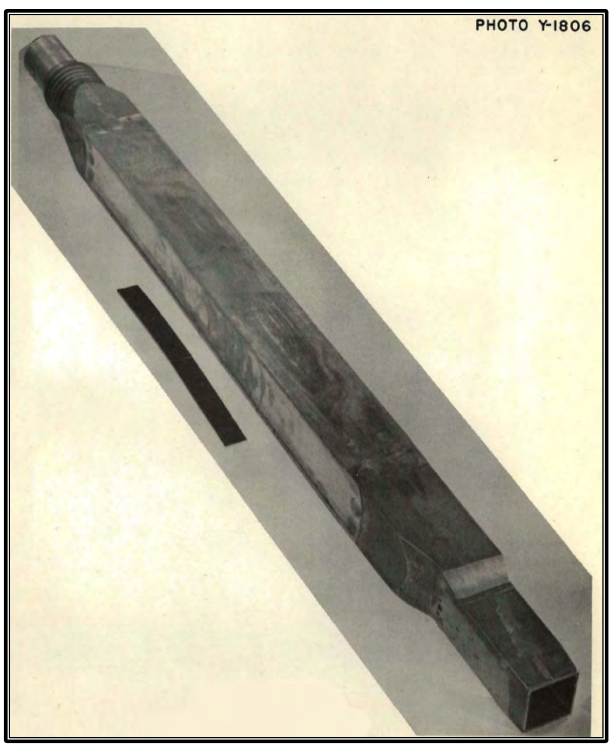


Figure 157. Archival photograph of the MTR complete fuel element assembly (ORNL Photo Y-1806) (Smith et al. 1951:11).

All subsequent reactors utilizing similar fuel elements would refer to those elements as "MTR-type." Fuel elements are defined as "core pieces that can be inserted into the [reactor] grid and that contain a fissionable material for use in the production of energy" (Operations Division Staff 1986:1-3). In a 2003 interview, Alvin Weinberg proclaimed "The greatest contribution to reactor technology really was the Materials Test Reactor [sic]" (Weinberg 2003:7). This sentiment persists in the minds of many former ORNL employees, including Bill Manly: "The fuel elements for MTR, the Eisenhower Reactor [also known as the Geneva Reactor], and the swimming pool reactor at the Bulk Shielding Reactor and Oak Ridge Research Reactor – all those are the same type of technology. The MTR was the 'father' of all those other reactors" (Manly 2003:18).

After Geneva, while constructing the ORR, researchers in both the Neutron Physics Division and the Operations Division determined the need for a simple critical facility for training and research. A versatile reactor could also be utilized for testing core configurations of the ORR as well as new instrumentation, shielding issues, and reactor physics. The Pool Critical Assembly (PCA) was constructed utilizing spare duplicate parts leftover from the Geneva Reactor and was completed in 1958 (Stanford 1970:1, 12; Rosenthal 2010:46). While similar to the BSR, the PCA differed by its capability to accept both BSR and ORR fuel elements in its stacked grid plate. The plate exhibiting round holes for BSR element end boxes sat on top of the plate with square holes for ORR fuel element end boxes, and the top BSR styled plate could be removed to expose the ORR plate. It was conveniently installed in the northwest corner of the BSR pool (Figures 158 and 159). Unlike the BSR, the PCA was static, and the BSR movable bridge was augmented to ensure the two reactor cores could not be located near enough to each other to produce a significant interaction. The Reactor Controls Department used the PCA to field test proposed modifications to either the BSR or ORR prior to execution. Meant to supplement the BSR and ORR programs, the PCA handled the majority of the lower-power experiments up to 10 kw. The PCA also provided a hands-on reactor training experience for the Oak Ridge School of Reactor Technology students as well as reactor operators for both ORNL and the Tennessee Valley Authority (Rosenthal 2010:46; Johnson 1960:1-2; Bates 1957:3).

The Graphite Reactor, operational and critical for precisely 20 years, was retired in 1963. ORNL had constructed the BSR and the requisite BSF with an expectation of a 10-year lifetime, however, the shutdown of the Graphite Reactor extended the life of the BSR as it shifted toward becoming a general-purpose research reactor. The BSR underwent numerous upgrades during this change. This included increasing the power level from one to two Mw, making the BSR available for a wider range of experimentation including tests run by the Solid State Division to study the impact of radiation on materials. Use of the BSR as a general-purpose research reactor expanded even further after the LITR was shut down on October 10, 1968, having been superseded by the reactors it helped spawn, such as the ORR. The BSR operated until March 1987, when the DOE ordered the shutdown of all ORNL research reactors in response to the Chernobyl and Three Mile Island incidents (Cagle and Casto 1968:1-3; Rogers 2018:8, 31; Rosenthal 2010:58; Stapleton 1993:9, 23).

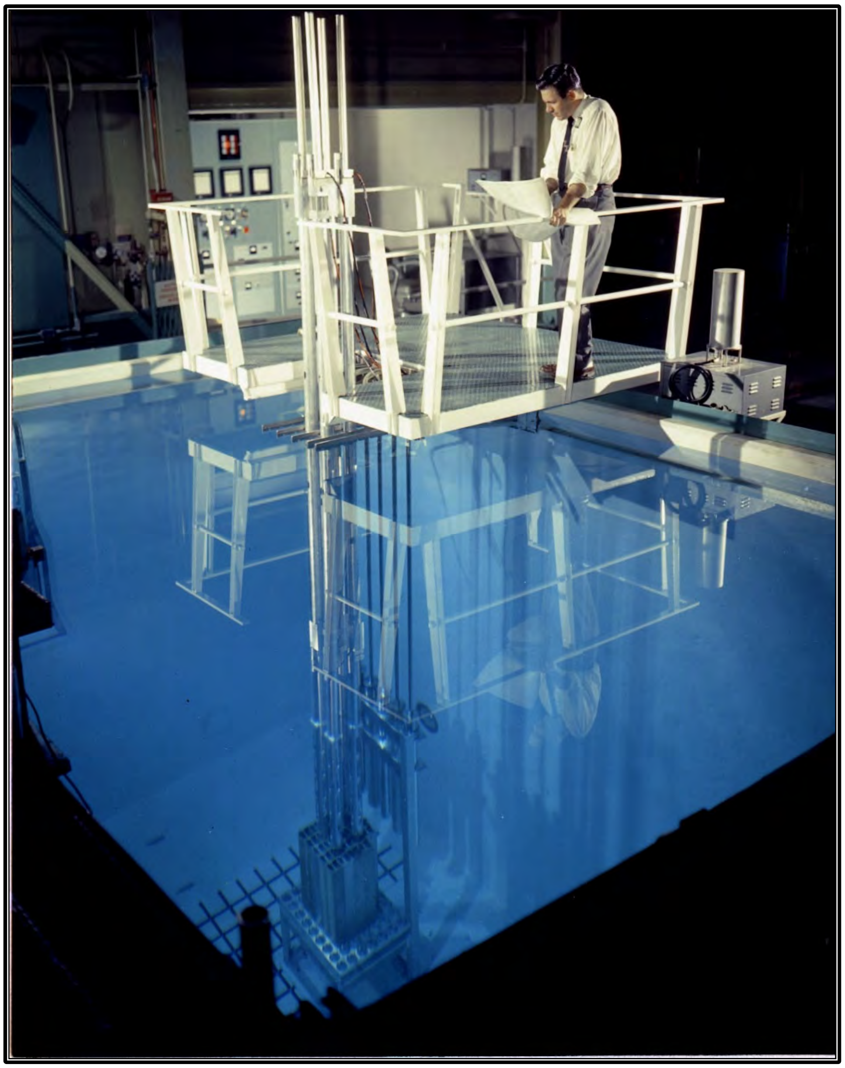


Figure 158. Archival photograph of the PCA in the BSF pool, circa 1958. The BSR fuel elements, inserted in the stacked grid plate, are visible at the bottom of the photograph (ORNL Photo 43038).

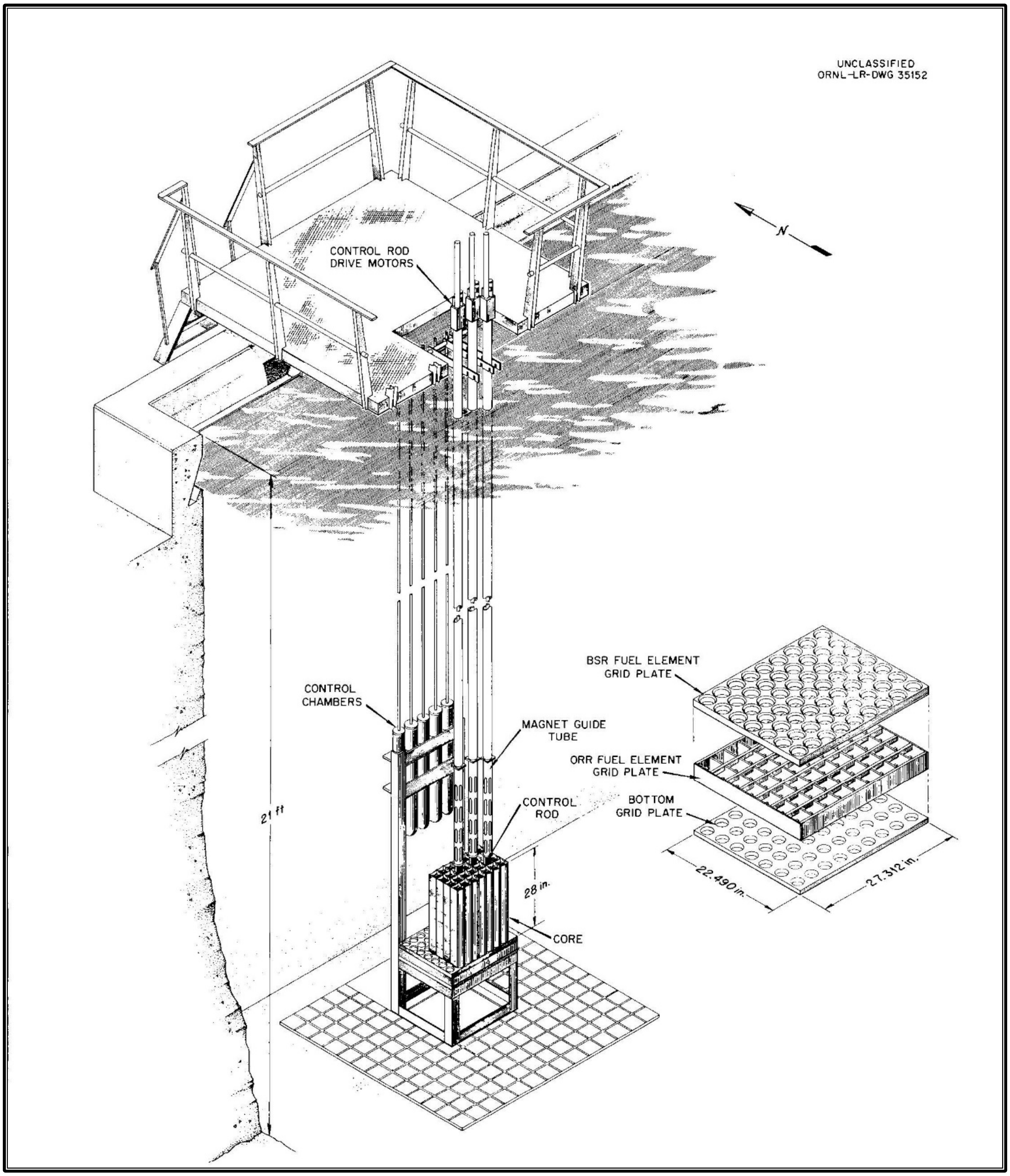


Figure 159. ORNL Drawing (ORNL-LR-DWG 35152) of the PCA, showing the detail of the stacked grid plats, circa 1960 (Johnson 1960:4).

The ORR Takes Shape

After losing the MTR to the National Reactor Testing Station in Idaho, ORNL continued to vie for a high-neutron-flux reactor to be built in Oak Ridge. In 1950, Arthur Snell, Director of the Physics Division, and Weinberg co-authored a proposal for a RIR to be built at X-10, or ORNL (Figures 160–163). "The research and production program of ORNL depends primarily upon the intense neutron fluxes available in the X-10 chain reactor. Since the original X-10 graphite reactor was built, those activities of ORNL which require neutrons have increased tremendously. These activities lie in the fields of isotope production, basic and applied physics, chemistry and biology, and reactor development. It is not surprising, therefore, that the Laboratory finds the present graphite reactor inadequate" (Snell and Weinberg 1950:4). Asserting that the Graphite Reactor was utilized at capacity and the MTR was inconveniently located for experimentation purposes, the proposal suggested the construction of a simplified MTR with a 3 Mw power level. The construction of a moderately high-flux reactor at ORNL, capable of meeting the rapidly escalating radioisotope demands, would preserve the centralization of radioisotope production at ORNL (Snell and Weinberg 1950:4-5).

The proposal described the RIR as an experimental reactor, located just east of the Graphite Reactor, and featuring higher thermal flux, much higher fast flux, and more intense neutron beams than the Graphite Reactor, as well as vertical and larger experimental access facilities. The proposal indicated the RIR would have a lower flux than the MTR, considering the location would be less isolated than that afforded by the MTR. The remoteness of the MTR, however, restricted the use of the facility. "It is, therefore, natural to expect that only those experiments will be sent to the MTR which require the very highest flux, and which do not require the day to day backing of a completely equipped national laboratory. In this category fall all those experiments which involve long term irradiation … and which do not require continuous monitoring" (Snell and Weinberg 1950:14). The proposal made repeated reference to the growing Isotope Distribution Program (IDP), which had recently received generous funding from the AEC for the construction of new processing facilities in preparation for the anticipated future demand. The Graphite Reactor struggled to generate radioisotopes at a rate that would fully utilize the capacity of these new facilities (Johnson and Schaffer 1992c:63; Snell and Weinberg 1950:6-9, 17). These opportunistic scientists and researchers, like Weinberg, recognized their chances of obtaining a high-neutron-flux reactor at ORNL depended upon clearly linking their proposal to the IDP, discussed further below in "The IDP and the Centralization of Radioisotope Production at ORNL" section.

In 1953, the AEC approved the construction of the high-neutron-flux reactor at ORNL, referred to in reports by May of that year as the ORNL Research Reactor or the acronym ORR, the design of which combined attributes of both the MTR and BSR (Johnson and Schaffer 1992d:104). The AEC supported the preliminary design work. During the first few years of design and construction, the ORR plan evolved significantly as emphasis leaned toward the numerous, expanding experimental programs at ORNL. Additionally, the mounting experience with the MTR, BSR, and LITR through the early 1950s informed ORR design improvements (Cole and Gill 1957:2).

The location of Building 3042 housing the ORR, selected for maximum convenience, was directly to the east of the Graphite Reactor (Building 3001), south of the LITR (Building 3005), and southwest of the BSR (Building 3010) (Figure 164). By grouping these four reactors, personnel, utilities, and equipment could be shared. Furthermore, close proximity increased the accessibility of facilities for experimenters (Wright 1956:5).

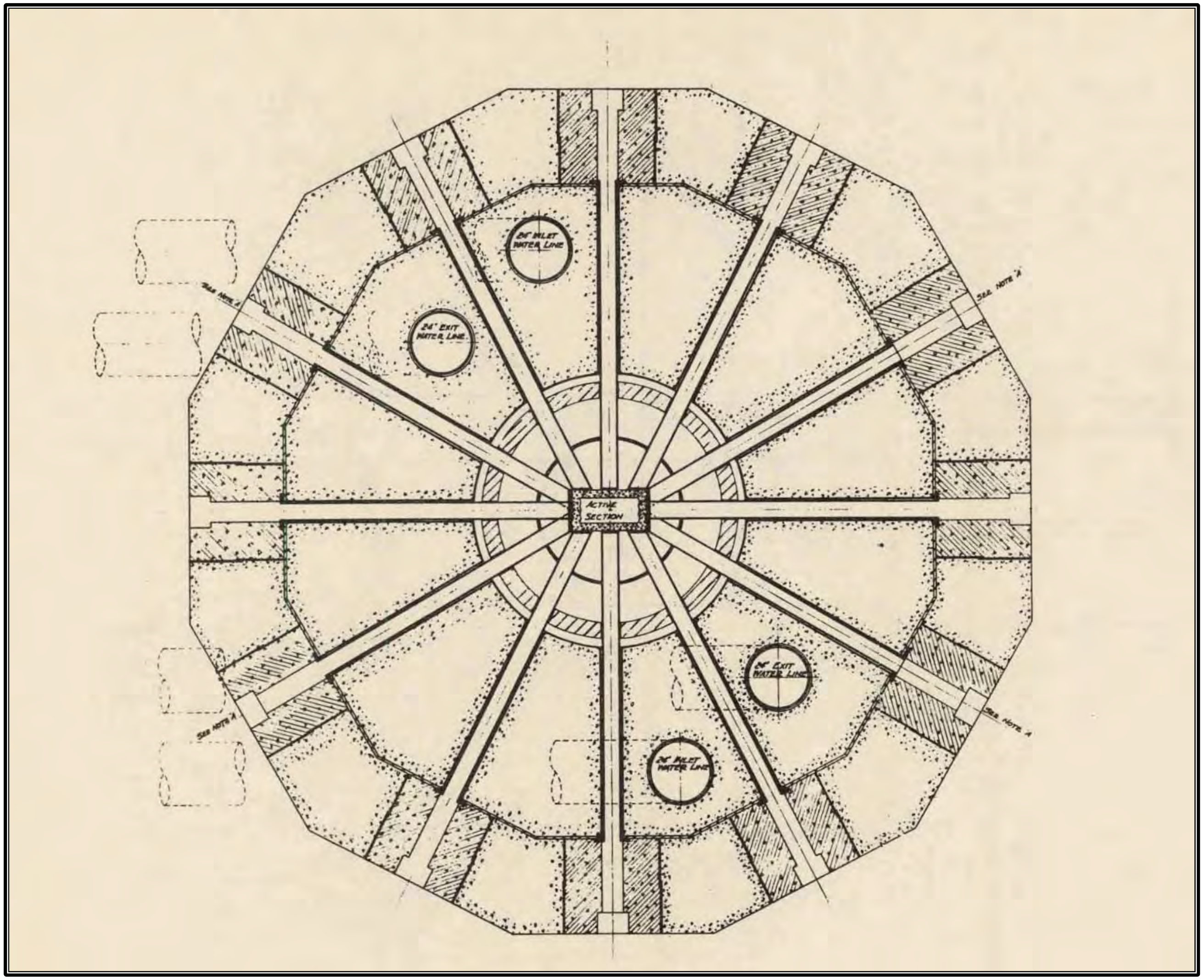


Figure 160. Drawing of the proposed RIR, showing a horizontal section of the reactor structure, circa 1950 (ORNL Drawing E-8139). Please note the HBs planned as experimental facilities (Snell and Weinberg 1950:41).

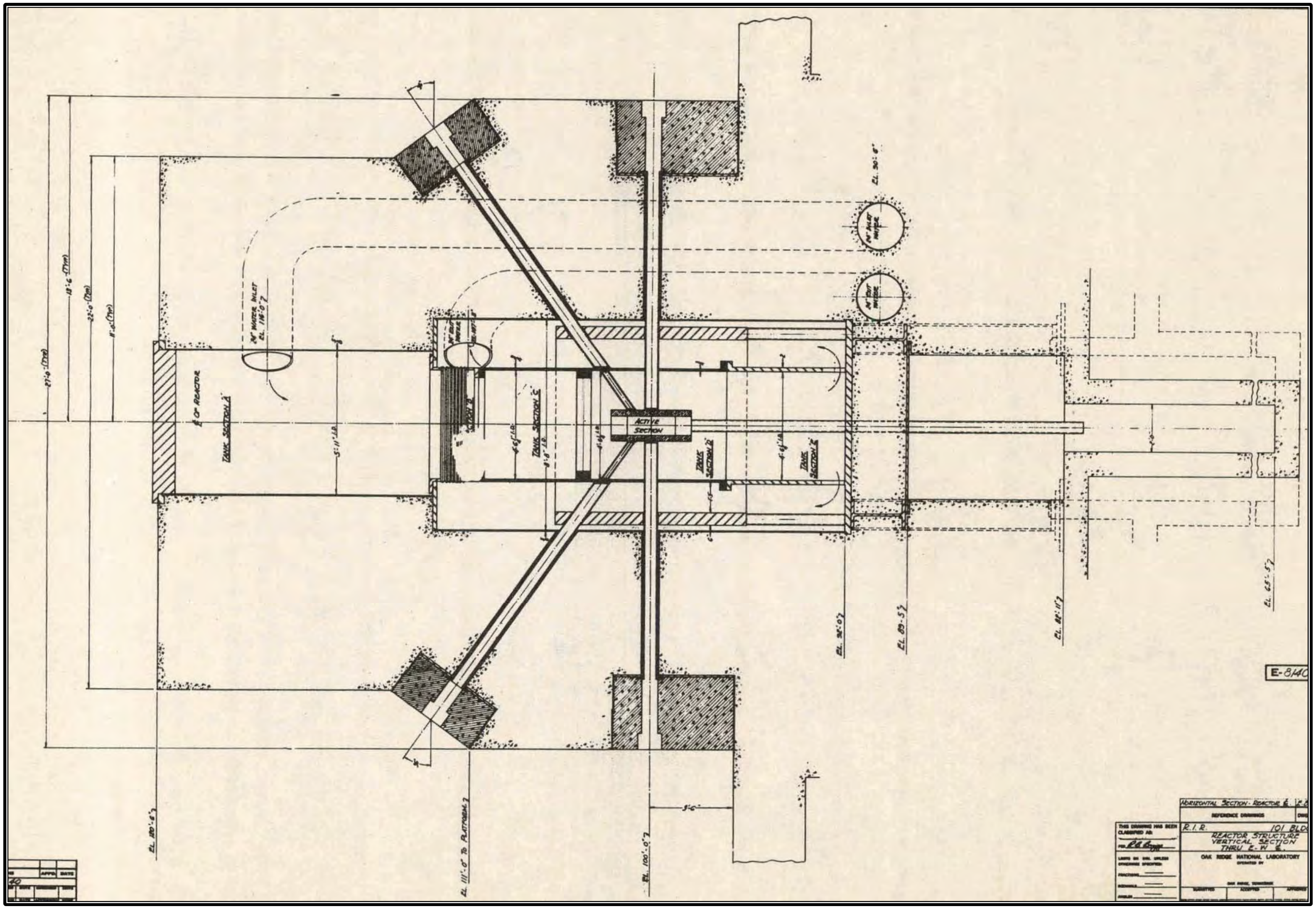


Figure 161. Drawing of the proposed RIR, showing an east to west vertical section of the reactor structure, circa 1950 (ORNL Drawing E-8140). Please note the horizontal and diagonal beam holes planned as experimental facilities (Snell and Weinberg 1950:42).

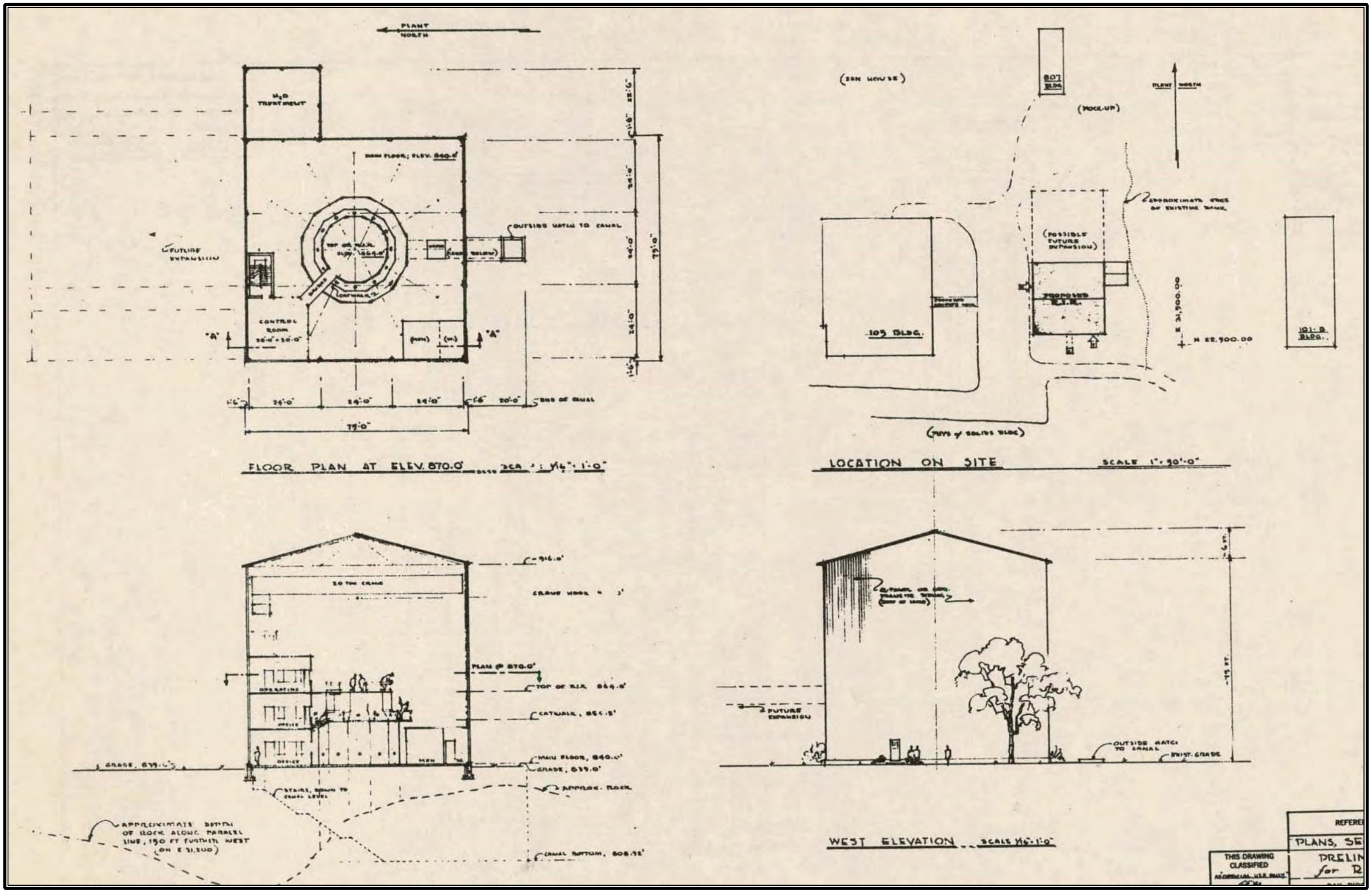


Figure 162. Drawing of the preliminary study for the building to house the proposed RIR, showing a floor plan, location, cross section, and west elevation, circa 1950 (ORNL Drawing TD-1881). Please note the suggested location of the proposed RIR building was east of Building 105 housing the Graphite Reactor (presently Building 3001) and south of the "Mock-up" which became the LITR (presently Building 3005). This is the present location of the ORR in Building 3042 (Snell and Weinberg 1950:43).

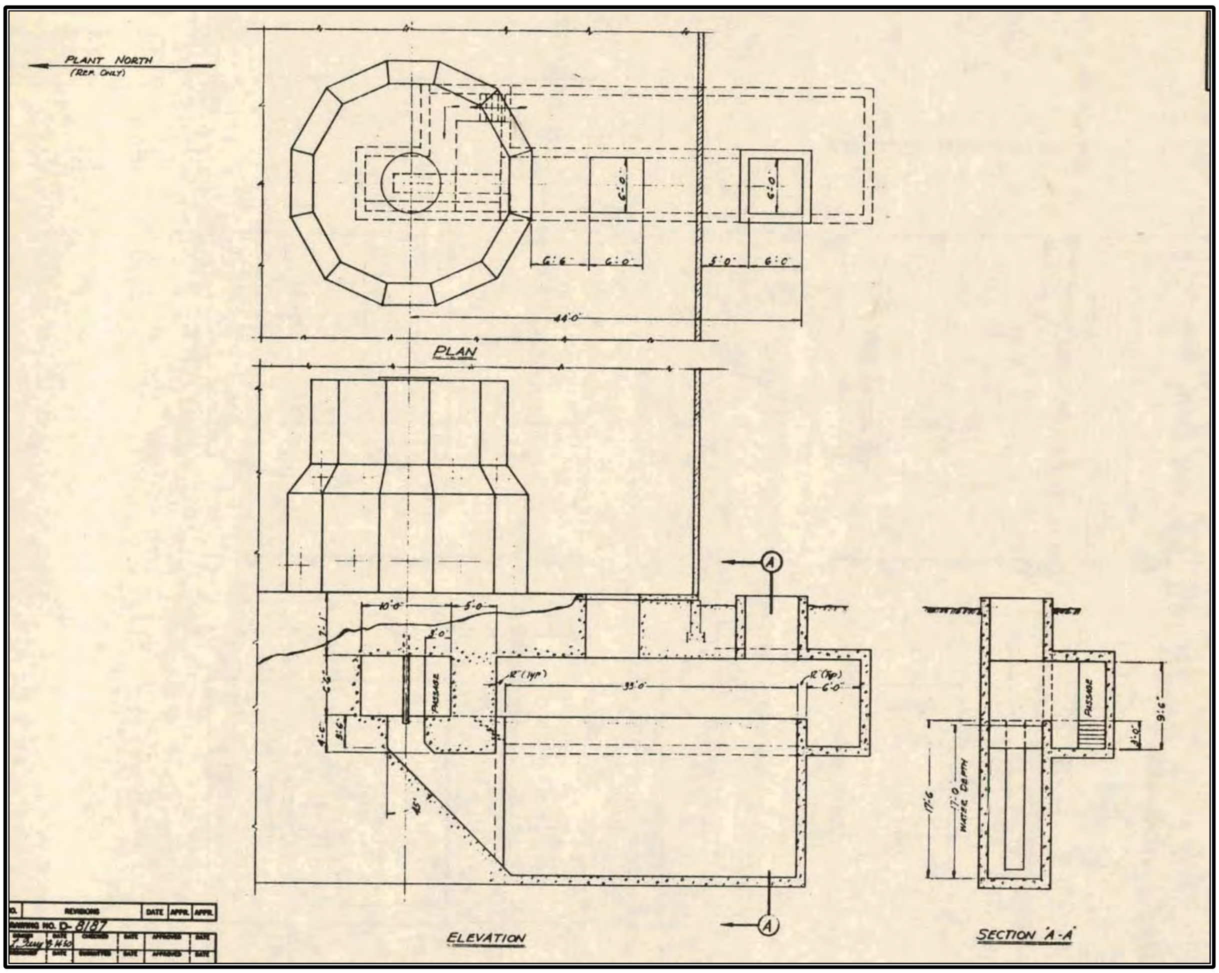


Figure 163. Drawing of the preliminary study for the canal layout planned to support the proposed RIR, circa 1950 (ORNL Drawing D-8187) (Snell and Weinberg 1950:44).

Figure 164. Aerial photograph depicting the location of Building 3042, housing the ORR, at center. Building 3001, housing the Graphite Reactor is at top right; Building 3005, housing the LITR, is at center right; and Building 3010, housing the BSR, is at bottom right (ORNL Photo 3239-2000).

ORNL scientists presumed by 1953 that the ORR would eventually attain power levels of 30 Mw, and, in order 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, but was calculated to be less expensive to update at a later time. The proposed shield design theoretically limited the radiation levels in the building to less than one-tenth the accepted biological tolerance, excepting the sub-pile room (see Figures 62 and 63). Plans for shielding depended upon calculations based on measurements taken at the BSF, as the core of the ORR and its general design were quite similar. The ORR shield was to be comprised of water (similar to the MTR and BSR designs), barytes concrete, lead, and iron (Figures 165–167). At this stage in development, planned experimental facilities involved 10 beam holes, 8 through-facility holes, and 2 instrument channels. These facilities allowed for the highest risk of radiation escape into the area of the building external to the reactor, therefore, solid plugs for each experimental facility were suggested to control potential gamma radiation leakage (Barkelew 1953:2–5; 18).

Shielding design considerations continued into 1954, and ORNL conducted an ORR shadow shield mockup experiment in the pool at the BSF in order to take gamma radiation measurements (Cochran et al. 1954:2). The BSR was used for numerous other studies regarding ORR construction, including the rate of gamma heating in structural materials and impacts of heavy water reflection near the ORR beam holes (Gill and Cole 1956:13). The ORR shield was reviewed further in 1958, prior to increasing the power level to 30 Mw, and determined to be “more than adequate” on the whole, but augmentation to the beam hole experimental facilities was again suggested, which the ORR Design Group provided (Zobel et al. 1958:1).

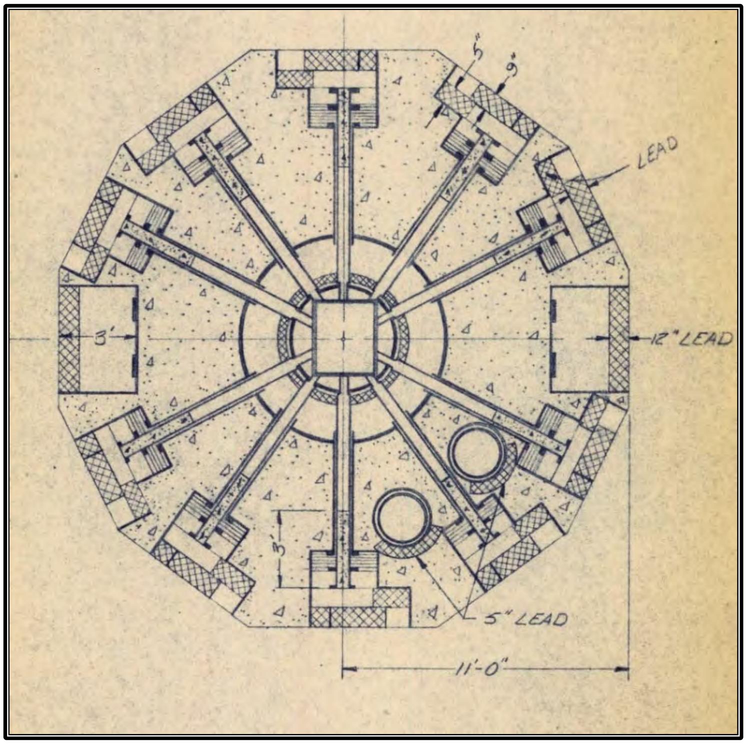


Figure 165. Shielding study drawing, showing a horizontal section of the proposed ORR design including the beam-hole facilities and shielding materials. The barytes concrete is represented by the dot and triangle pattern and the lead is marked (Barkelew 1953:21).

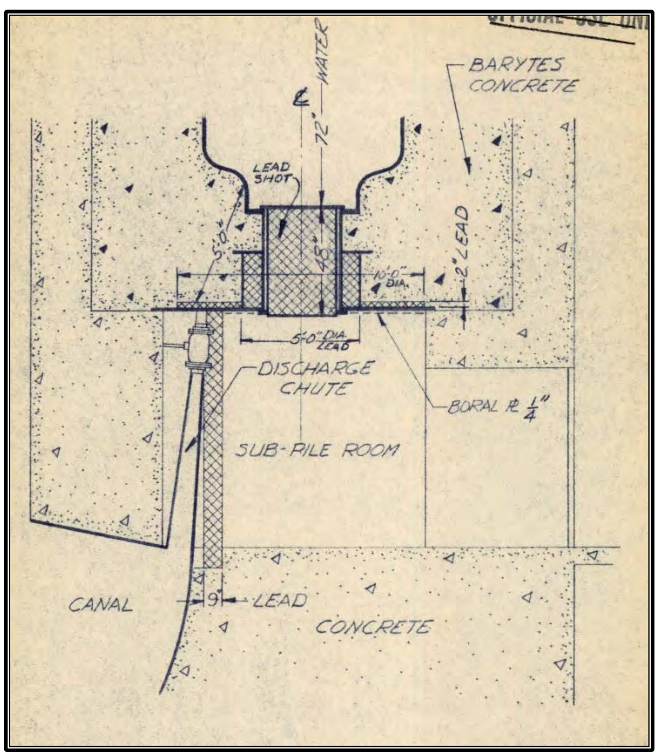


Figure 166. Shielding study drawing, showing a vertical section of the proposed sub-pile room design. The locations of water, lead, and barytes concrete are marked (Barkelew 1953:23).

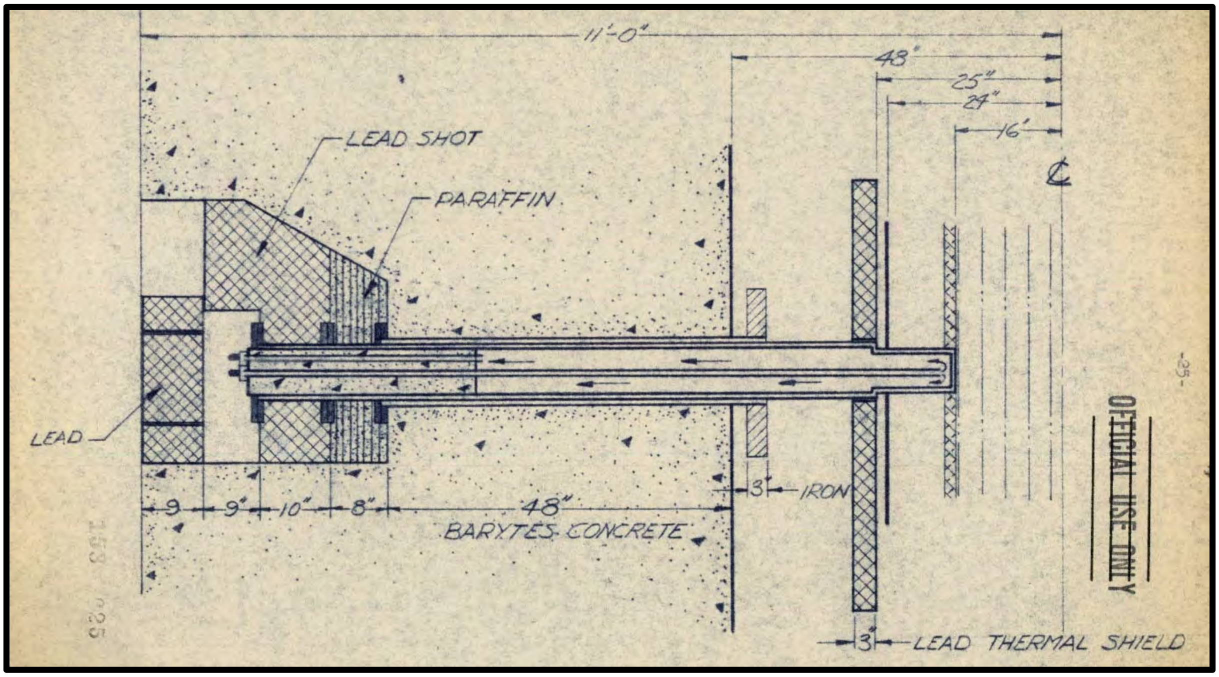


Figure 167. Shielding study drawing, showing a vertical section of a proposed typical beam-hole design. The locations of lead, paraffin, iron, and barytes concrete are marked (Barkelew 1953:25).

ORNL submitted the preliminary design proposal for the ORR to the AEC in March 1954. The McPherson Company of Greenville, South Carolina won the contract for the building, reactor shielding structure, and cooling system designs on July 21. Blount Brothers Construction Company of Montgomery, Alabama constructed the building, shielding, and cooling system and provided an estimated completion date of summer 1957. Modifications to the design occurred in 1954 and 1955, to include preparations for 20 Mw operation. The ANP Program and HRE requirements inspired this initial power level increase, which was approved by the Advisory Committee on Reactor Safeguards in March 1955, on the condition that: "(a) Containment is to be provided to the extent that an accident releasing the volatile fission product gases from the reactor core will not constitute a widespread hazard; (b) Available excess reactivity is to be minimized in so far as practical; (c) That the experimental installation in the engineering test facilities be restricted so that upon failure or malfunction of the installation no more than 1.4% reactivity will be added to the reactor" (Cole and Gill 1957:3-4).

The Operations Division reported in September 1955 that excavation for the ORR was almost complete and installation of the footings had begun (Rupp 1955:6). On February 23, 1956, ORNL hosted a Steering Committee Meeting to discuss experimenters' requests for space at the ORR. This review resulted in a proposal to the AEC for additional funds to finance a second floor, air-conditioning in the entire building, two hot cells (one located above the canal and the other for chemistry experiments involving short-lived radioisotopes), a freight elevator, and a cryostat room. By May, the AEC approved the request for $275,000 in supplementary funds for these enhancements. At this time, the reactor structure foundations were complete and reactor installation was estimated for October 1, 1956. ORR Progress Reports, however, consistently indicated that building construction was behind schedule and the contractor's work required regular and thorough inspection (Gill and Cole 1956:2-5).

While impatiently awaiting completion of Building 3042 and the reactor shielding structure, ORNL sorted out utility and facility details, such as plans for the cooling system water supply and fuel element design. In lieu of buying expensive new equipment, the ORR decided to attain demineralized water from the existing water system by revamping the schedules to produce the water needed over a longer period of time (Rupp 1955:6). The ORR required this water for use both in the cooling system as well as in experiments (Wright 1956:31). The ORR fuel elements differed slightly from those in the MTR, so ORNL determined it prudent to conduct hydraulic tests. These experiments took place in Building 9201-3 at Y-12 and were used "to verify the pressure drop calculations and to observe the flow distribution in the various channels" (Gill and Cole 1956:13). Experimental results coincided very closely to the calculated estimates. They deemed the design satisfactory and in final form for use in the ORR (Bettis 1956:1-3). Anticipating the opening of the ORR to be just on the horizon, future ORR personnel began training at the MTR by September 1955. ORNL planned to hire several new operators through the end of that year to allow ample time for training (Rupp 1955:6). During construction of Building 3042, the ORNL Carpentry Shop built two scale models of the ORR in 1956 (Figures 168–170) (Gill and Cole 1956:14).

The AEC had anticipated the ORR would begin operations in 1957 (Libby et al. 1957:351). ORNL did not gain control of Building 3042 and the ORR until July 15 that year. They spent the beginning of 1957 designing, fabricating, and purchasing equipment while preparing for tests and, ultimately, operation of the ORR. The Laboratory constructed a mockup of the reactor mechanical controls which they tested with dummy fuel and reflectors under simulated operating conditions at the Graphite Reactor in Building 3001 (Cox and Casto 1958:1-3). The reactor vessel, comprised of two pieces including the reactor tank and the top of the vessel, was initially fabricated by O. G. Kelley Company of Johnson City, Tennessee. ORNL personnel modified the reactor tank in 1957 to include additional openings to satisfy the Army Package Power Reactor Project in progress at that time (Figures 170–173) (Gill and Cole 1956:2-5).

After July of 1957, ORNL began training personnel inside the building (Figure 174). The Operations Division conducted flushing and cleaning tests on the water systems, including the reactor cooling system, the pool system, and varied bypass circuits of the primary system. These initial procedures revealed numerous desirable changes, primarily to allow for fully remote operation and increased efficiency. This Division also set up hydraulic testing equipment within the reactor vessel beginning October 25, 1957 and, by November 24, they conducted hydraulic reactor tests. When these tests were not being conducted, reactor installation continued. The final stage of reactor installation and its requisite equipment began on December 11, after which a final test was performed (Cox and Casto 1958:1-3). Staff installed the reactor tank in the ORR pool early in 1958 (Figures 175 and 176). Both the North and South Hot Cells, called for during the 1956 Steering Committee Meeting, were constructed and completed in 1958 as well (Figures 177 and 178).

While construction of the ORR progressed, the Soviet Union completed the design of the first reactor to outpace the neutron flux of the MTR. The United States, committed to spare no effort in outdoing the Soviets throughout the Cold War, responded to this Soviet achievement with determination. ORNL pressed the AEC to approve a program to develop a "very high-flux research reactor," and this request found support in Washington. Weinberg referred to this design as a "super-duper cooker" and it would become the HFIR, completed in 1965 (Figure 179). The HFIR, described as "trapping a reactor neutron flux inside a cylinder encasing water-cooled targets," allowed for transuranic element study, amplified radioisotope production, and provided beam ports for experiment access (Johnson and Schaffer 1992e:148–150). The HFIR would ultimately outlive the ORR and is still in operation at the time of this recordation.

ORNL designed the ORR to use MTR-type fuel elements and beryllium reflector pieces placed in a seven-element by nine-element grid assembly (Figure 180). The reactor core was enclosed in a tank and cooled by a forced circulation of demineralized water. The reactor tank was completely submerged in a pool of water. The pool water was contained by walls and a floor comprised of barytes concrete, which provided structural support as well as shielding (Figure 181, see Figures 17, 19, 20, 22, 139–142, 165–167, and 175). The fuel elements, grid assembly, reactor tank, and heat exchanger were all composed of aluminum alloys (Neumann 1961:2). The Reactor Operations Department, nested within the Operations Division, would manage operation of the ORR in addition to the LITR and Graphite Reactor (Cole and Gill 1957:1, 42). The ORR went critical on March 21, 1958 and began routine operations on July 20 that same year (Figures 182–185). The reactor operated at 20 Mw power between April 1958 and July 1960. Modifications were made over the summer after the AEC provided permission to raise the power level and it attained 30 Mw power by August 1960 (Tabor and Costner 1962:3; Hamrick and Swanks 1968:2). By 1959, ORR personnel established an operation schedule of three weeks in operation followed by one week in shutdown, allowing for experiment installation, minor repairs, and recalibration as necessary (Casto 1959b:89). Upon completion, the entire ORR installation totaled approximately five million dollars (Thompson 1963:72).

Figure 168. Archival photograph, undated, showing the two scale models of the ORR on display (ORNL Photo 41209).

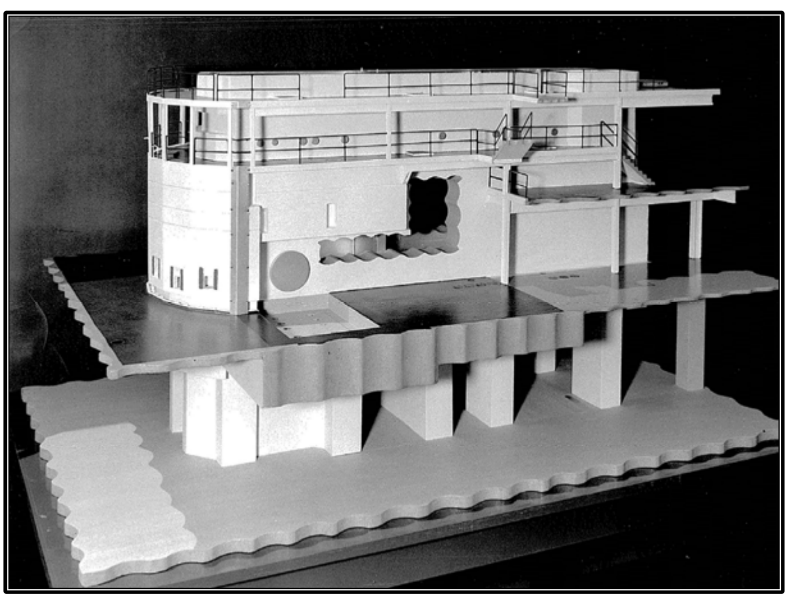


Figure 169. Archival photograph, undated, showing a detailed view of the scale model showing the north elevation of the ORR reactor structure, including the basement, first floor, second floor, perimeter balcony, and third floor (ORNL Photo 18096).

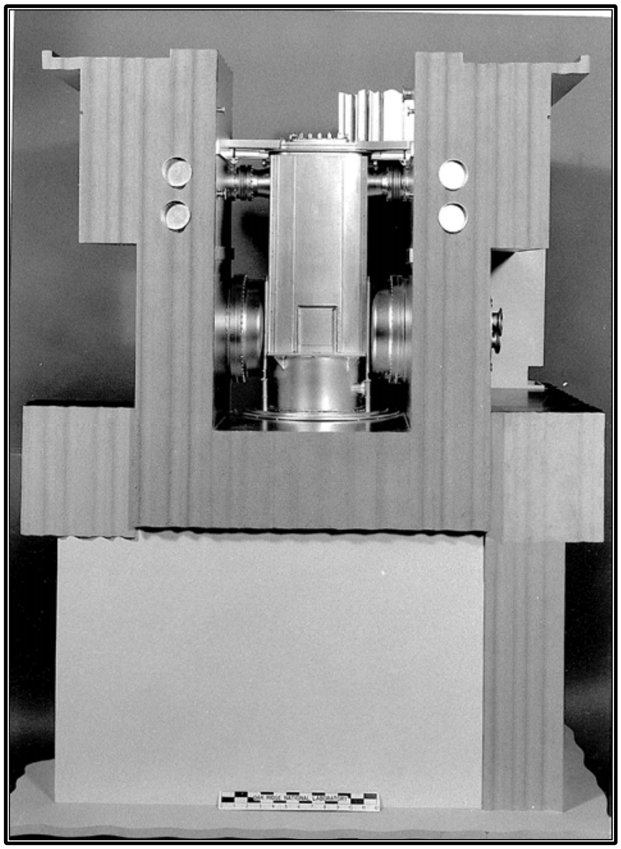


Figure 170. Archival photograph, undated, showing a detailed view of the scale model showing a vertical section of the ORR reactor structure and shielding (ORNL Photo 19593).

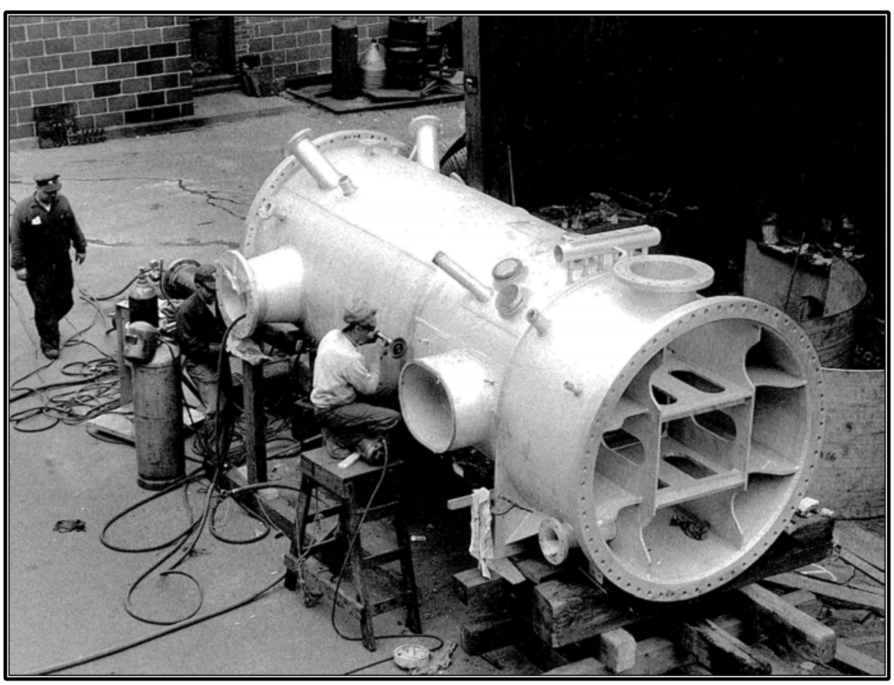


Figure 171. Archival photograph showing employees modifying the reactor tank for the ORR, circa 1957 (ORNL Photo 41130).

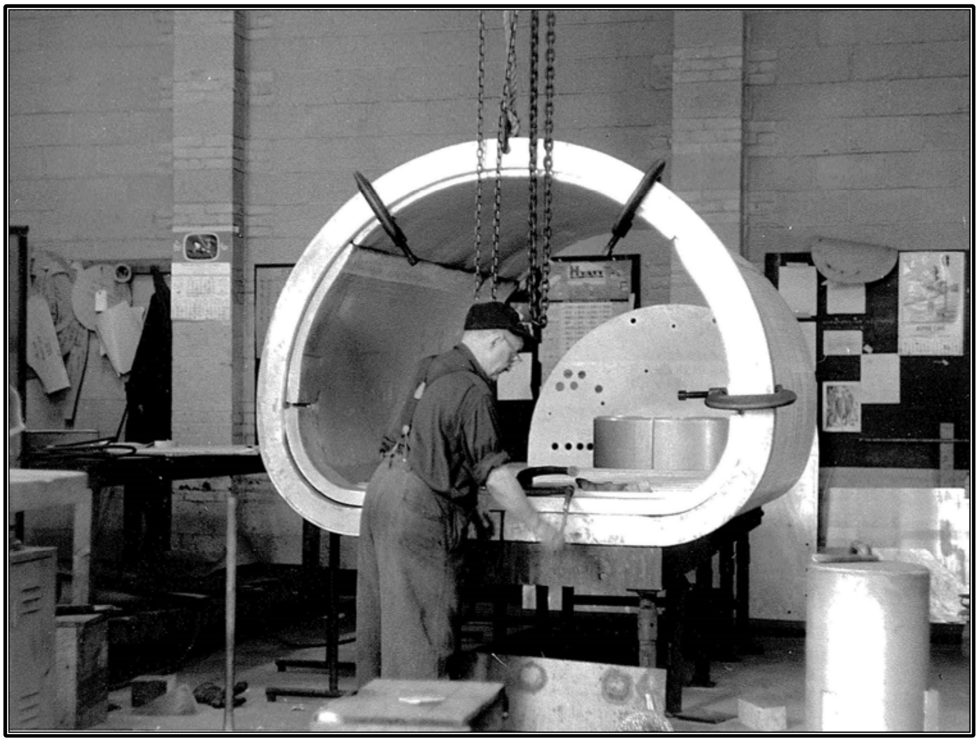


Figure 172. Archival photograph showing an employee working with the top of the reactor vessel, to be fitted onto the top of the reactor tank, circa 1957 (ORNL Photo 41136).

Figure 173. Archival photograph showing the top of the reactor vessel being fitted to the reactor tank, circa 1957 (ORNL Photo 41129).

Figure 174. Archival photograph showing personnel training in the ORR Control Room in Building 3042, circa 1957 (ORNL Photo 41464).

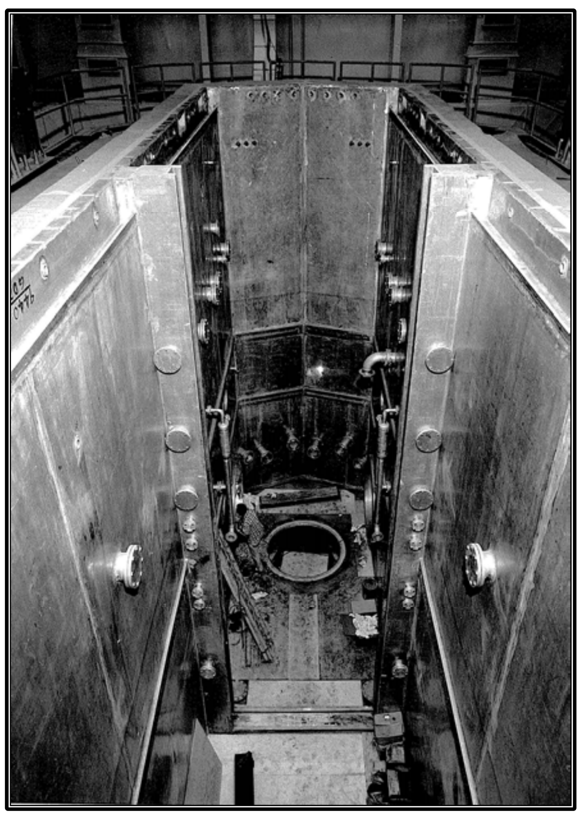


Figure 175. Archival photograph, circa 1957, showing the ORR pool prior to the installation of the reactor tank in early 1958 (ORNL Photo 41281).

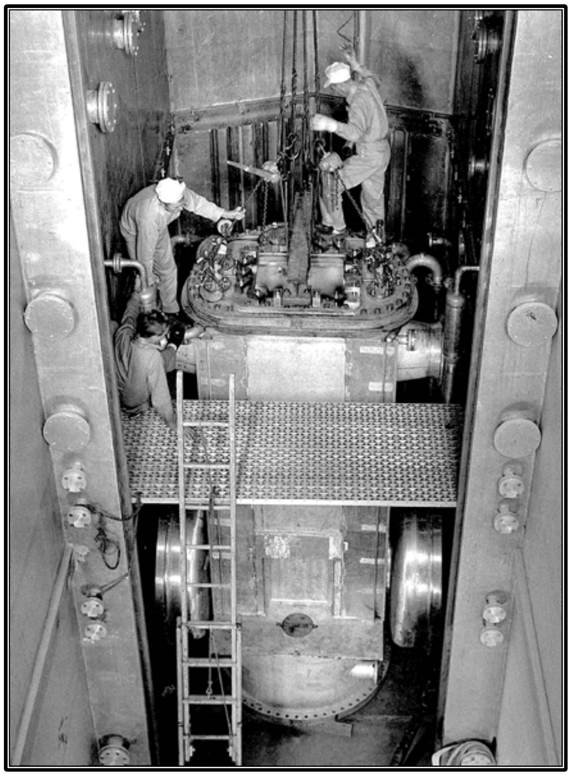


Figure 176. Archival photograph showing personnel installing the reactor tank in the ORR pool circa 1958 (ORNL Photo 43991).

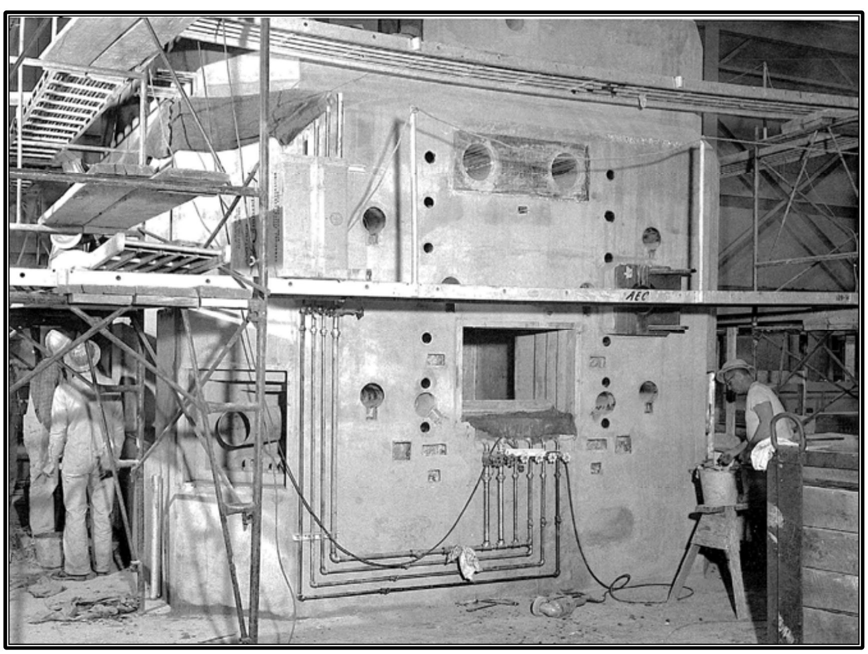


Figure 177. Archival photograph showing the North Hot Cell in Building 3042 at the ORR after pouring the concrete shielding, circa 1958 (ORNL Photo 42590).

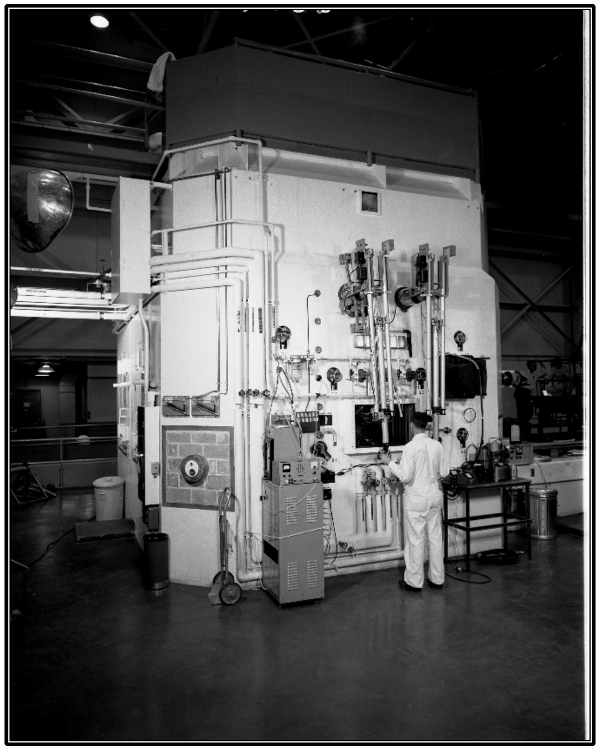


Figure 178. Archival photograph showing the hot cell area at the west end of the reactor structure in Building 3042 (ORNL Photo 48951).

Figure 179. Archival photograph of the HFIR after completion, circa 1965. The HFIR was designed to provide a higher steady-state neutron flux than the ORR. Still in operation at the time of this writing, the HFIR is used to produce super heavy elements and for neutron science and material research (Rumsey 2018).

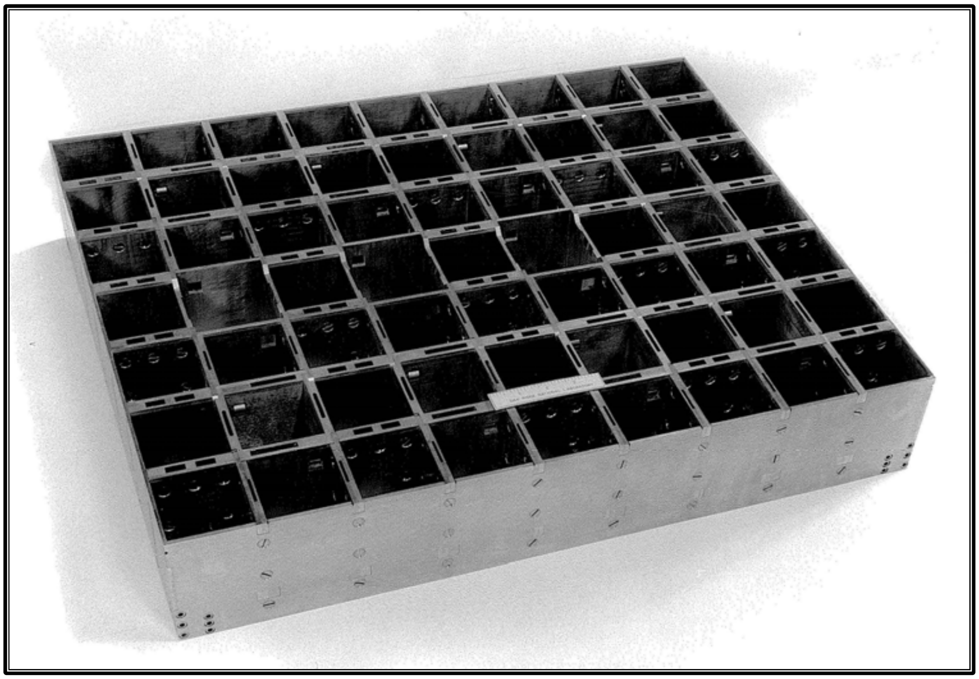


Figure 180. Archival photograph showing the seven by nine grid assembly to be located within the ORR core, circa 1956 (ORNL Photo 19547).

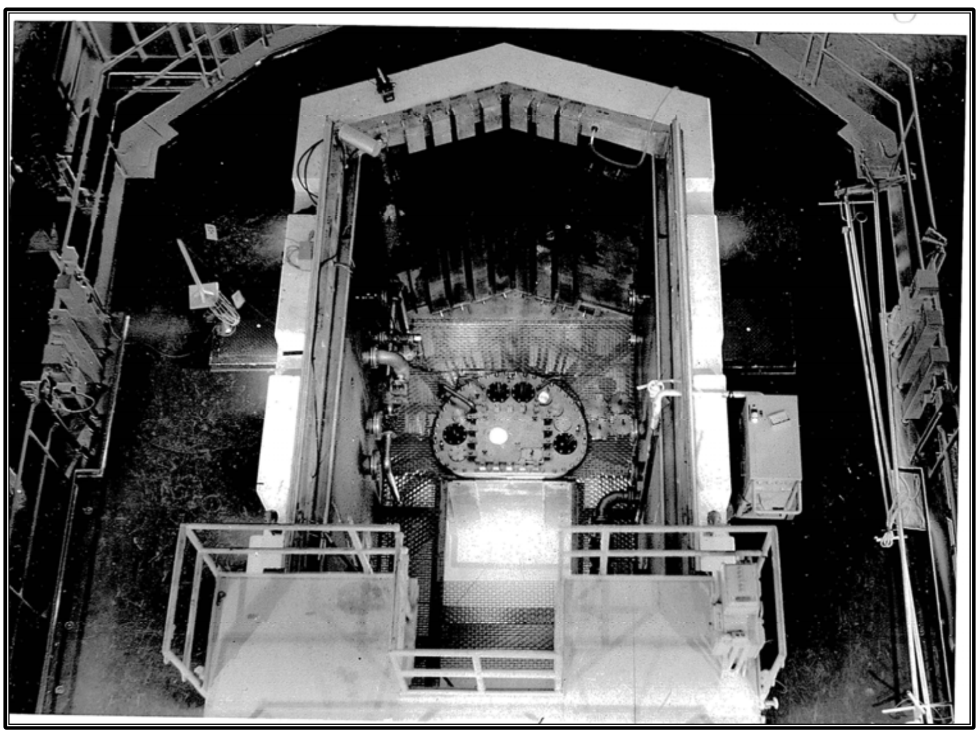


Figure 181. Archival photograph showing the ORR core submerged in a pool of water surrounded by concrete walls, circa 1958 (ORNL Photo 44809).

Figure 182. Archival photograph taken in the Control Room at the ORR in Building 3042, the day the reactor went critical, March 21, 1958 (ORNL Photo 3206).

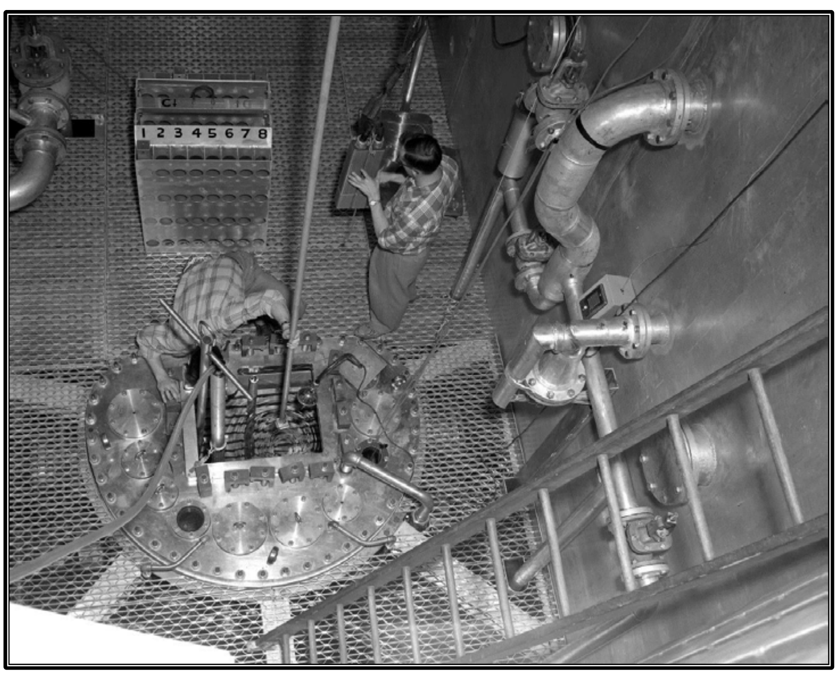


Figure 183. Archival photograph taken within the reactor structure, at the reactor tank top, at the ORR in Building 3042, the day the reactor went critical, March 21, 1958 (ORNL Photo 3208).

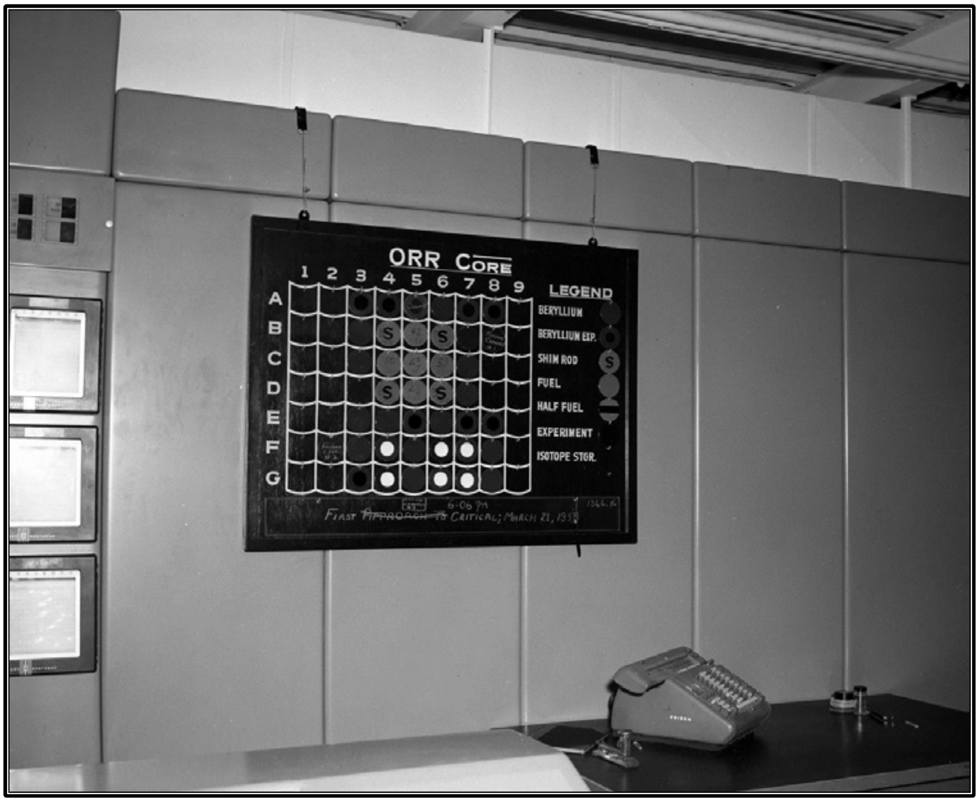


Figure 184. Archival photograph showing the ORR Core configuration board in the Control Room of Building 3042 on the day the reactor went critical, March 21, 1958 (ORNL Photo 3210).

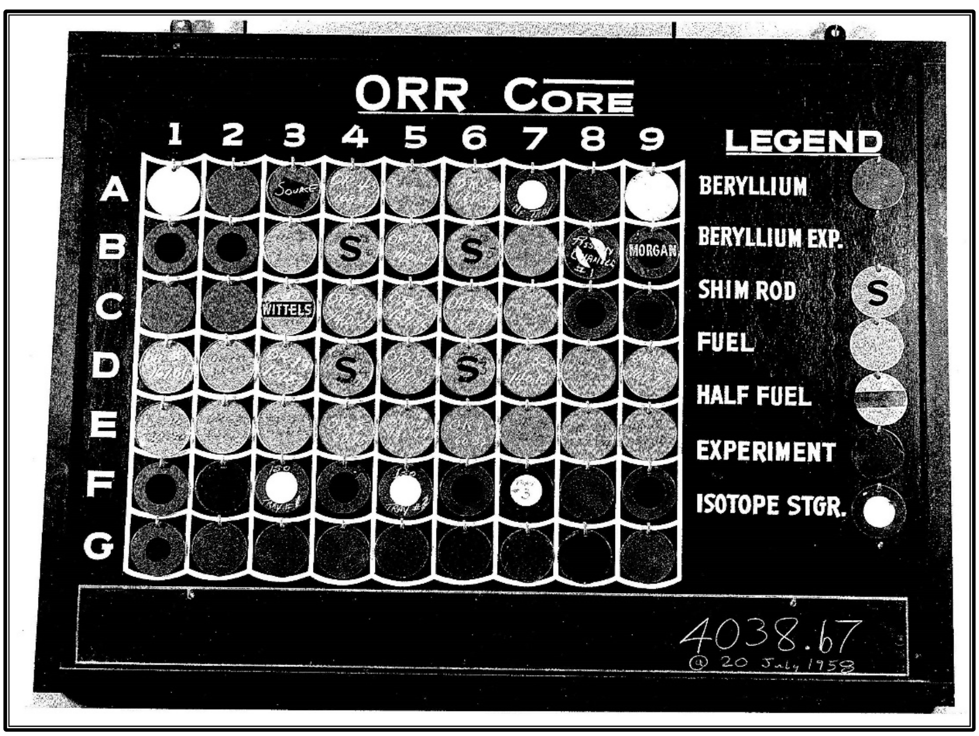


Figure 185. Archival photograph showing the ORR core configuration board in the Control Room of Building 3042 on the day the reactor began routine operations, July 20, 1958 (ORNL Photo 44506).

Reactor Policies, the Committees, and Resource Consolidation

The primary motivation for ORNL to construct the ORR in its current location was accessibility. By grouping the four reactors – the Graphite Reactor, the LITR, the BSR, and the ORR – in one area of the Laboratory, they consolidated resources, such as personnel, utilities, and equipment (see Figure 164). The close proximity was also convenient for researchers' experimental needs (Wright 1956:5). In 1956, before completion of the ORR, the Operations Division managed all ORNL reactors. This Division published a document titled "Administrative Control of a Research Reactor" in which it outlined training requirements and safety measures in place at that time. The same group operated both the Graphite Reactor and LITR in the mid-1950s, overseeing safe operation as well as providing light support to researchers as needed. Training guides had been written, locks with inter-locking keys were installed in the control rooms, and the Reactor Operations Review Committee was in place, organized of senior staff members that would annually review the operations of each ORNL reactor. Reactor personnel were responsible for managing their own radiation exposure; however, a record of daily exposure per person was also maintained (Cox 1956:1-3).

On July 1, 1955 ORNL created the Applied Nuclear Physics Division by combining the parts of the Physics Division most focused on critical experiments and reactor shielding with a theoretical reactor physics group under the Director's Division (Blizard 1956:v). This Division was renamed the Neutron Physics Division sometime before 1957 and it absorbed the responsibilities of managing all ORNL reactors. Therefore, the ORR became operational while under the management of the Neutron Physics Division. In 1964, the Operations Division once again assumed responsibility of all ORNL reactors, including the ORR.

Rube McCord, who worked with reactors and reactor technology at ORNL for four decades and served as a shift supervisor at the ORR for a period of time, remembered the 1950s and 1960s as "when procedures really came into vogue. Up till then, things weren't as formalized" (McCord 2003:11). ORNL established a Radiation Safety and Control Department early in 1960 with the responsibility of generating policies to minimize potential personnel exposures and property or environmental contamination or damage. In the first few days of 1961, the AEC site at Idaho Falls suffered a prompt critical accident that caused three fatalities and destroyed the Stationary Low-Power Reactor Number One, also known as the SL-1. After this incident, ORNL added an engineer to the Radiation Safety and Control Department staff in response to the AEC directive to re-evaluate and annually review all nuclear reactors under their purview. The subsequent Containment Program, generated through cooperation between this Department and most ORNL divisions, included the modification of the ORR off-gas system for in-pile experiments, completed in November 1961. Additions to Building 3042's ventilation and filtration systems were also noted for future renovation, but considered less urgent. This Department also participated in establishing guidelines for upgrading the scrubber system at the ORR and generated a Laboratory Radiation Safety Policy. All experiments planned for the ORR were, from this point, subjected to review first by the Operations Division and then referred to the Reactor Experiment Review Committee nested within the Neutron Physics Division. Surveillance of all reactors at ORNL as well as the Critical Experiments Facility continued to be the responsibility of the Reactor Operations Review Committee (Bruce n.d.:4, 6–9, 14, 21).

Shortly after these reactor reviews began and stringent policies became implemented, the Graphite Reactor was retired in 1963. Remote operation of the LITR had been established at the Graphite Reactor in 1957, therefore required relocation. The remote operations of the LITR thusly moved to the ORR control room. On May 31, 1967, remote operation of the BSR was also established in the ORR control room (Figure 186) (Cox and Casto 1958:16; Cagle and Casto 1968:1-3; Tabor 1967:4).

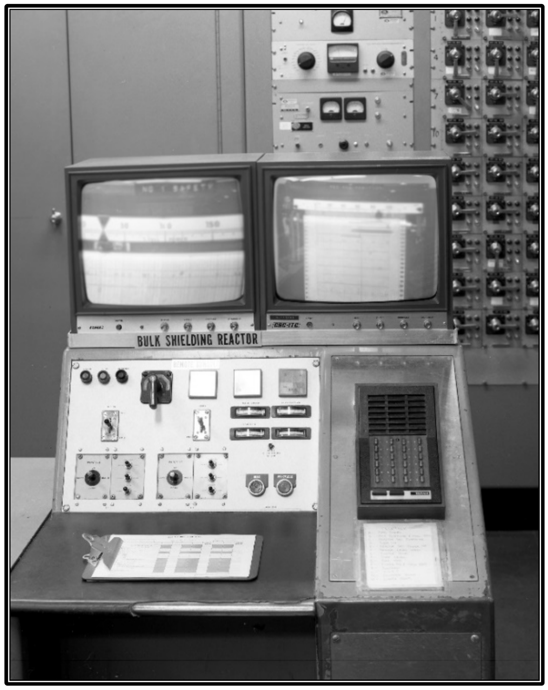


Figure 186. Archival photograph of the BSR remote controls in the ORR control room, undated (ORNL Photo 4270-82r).

As the nuclear reactors available at ORNL had multiplied, researchers began to compare the usefulness of the various facilities. The ORR, by comparison to its neighbors, offered the highest neutron flux and therefore best suited 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 (George 1962:2, 21-24).

Flexible and Safe Design

Given the experience ORNL and the AEC amassed in use of reactors to date, the design of the ORR allowed for flexibility as they anticipated its use may shift over time. 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 (Wright 1956:8-9; 14-17). Due to the location of Building 3042 in the middle of the Laboratory, the building housed numerous activities unrelated to ORR operation or its experimental programs. Work conducted in office spaces, an instrument shop, and a mechanical maintenance shop supported general needs of the Laboratory, particularly the Operations Division that oversaw the four reactors (the Graphite Reactor, LITR, BSR, and ORR) which were all located in close proximity in the central ORNL campus. (Tabor and Costner 1962:79). The usage of these auxiliary rooms on the north and south sides of the building frequently shifted, making the movable metal partitions particularly convenient. Additionally, the change room facilities in the 1957 Change House addition were utilized by staff from multiple divisions who worked in different buildings in the central campus.

The floor area surrounding the Reactor Structure remained open for experimental work. In front of the two large engineering test facilities, depressions in the floor slab contained a hatch to the basement. This design provided the opportunity for a concrete block cell to be constructed around these facilities as needed for experimentation and shielding purposes. The hatch opening allowed for remote manipulation and relocation of the experiment into another shielded cell located in the basement, in order to dismantle or store the experiment as the radiation decayed. On the third floor, an empty space with ample floor support remained to accommodate a future "hot" cell west of the Reactor Structure; this potential plan was realized by the addition of two hot cells constructed circa 1958. Wall recesses were also made in the pool wall to allow for additional shielded cells to be later constructed over the pool. At the outset, neither lab equipment or furniture was provided in the building, as plans fluctuated (Wright 1956:8–9; 14–17). New facilities were added around the reactor structure over the years, utilizing some of these design considerations. Furthermore, remote operation technology had advanced at ORNL by the time the ORR was completed and personnel could perform all routine operations for the ORR from the Control Room, meeting safety and efficiency requirements (Hamrick and Swanks 1968:5).

Another unique and convenient feature of the ORR was the lack of an upper grid plate, permitting experiments to remain in the core region during refueling (Hamrick and Swanks 1968:2). With the control-rod drives at the bottom of the reactor tank, the top of the tank welcomed multiple experiments which did not have to be removed during refueling. Due to its location submerged in water, refueling proved to be quick and simple, conducted in just a few hours. The spent fuel elements were stored in the pool near the reactor tank while the xenon poison decayed. All the fuel could be removed prior to changing out experiments in the facilities, reducing radiation hazards (Cox 1959:1; Thompson 1963:74).

Despite the built-in flexibility, staff encountered numerous spatial constraints within just the first four years of ORR operation. Offices housed numerous divisions and the building layout led to crowding of critical areas. Additional shielding necessitated as experiments actualized cut into vital floor space. The mechanical maintenance activities quickly outgrew the shop provided in the building, therefore ORNL constructed a small building nearby to house this work. Eventually, these maintenance activities occupied the basement. Personnel discussed several potential solutions to the overcrowding. Ultimately most of these proposed expansions to the facility never actualized. By 1962, however, ORNL built a gallery for visitors and trainees in order to reduce traffic in the Control Room. Additionally, the minimal exterior additions made over the years discussed above likely alleviated storage problems to a certain extent (Tabor and Costner 1962:79–84).

Plans for the ORR necessitated flexibility in preparation for the expected evolution of the facility. This also required careful safety considerations. With the anticipated eventual power level of 30 Mw, the ORR would ultimately attain a power level ten times that of the LITR. In 1958, the year the ORR achieved criticality, the LITR operated at 3 Mw, the BSR at 1 Mw (later 2 Mw), and the Graphite Reactor at 3.5 Mw (Figure 187) (Rosenthal 2010:8). Considering the closer proximity of the ORR to human populations than that of the MTR, safety was considered paramount. Researchers published studies considering a "maximum credible accident" and proposed engineering solutions to be adapted during initial construction that provided comprehensive containment should such an incident occur (Binford and Burnett 1956). Many safety features were therefore incorporated into the design to protect the surrounding area in the case of an accident. For example, a four-inch curb circumvented the floor on the first level of the building, to prevent any water leakage into the surrounding area in the event of a water leak from the Reactor Structure or any accompanying water lines. All first floor external entries also included four-inch ramps. These design features would, in theory, direct all water flow into the basement of the building, except in the occurrence of a massive pool rupture. Additionally, the first floor hatch, covered by steel doors, remained closed unless in use for fire containment purposes and the north and south elevations contained emergency escape personnel doors (Wright 1956:10–12).

Name	Thermal power, MW	Years operated
Air-cooled, graphite-moderated		
Graphite Reactor (Oak Ridge Pile, X-10 Pile)	3.5	1943–63
Aqueous homogeneous		
Homogeneous Reactor Experiment (HRE)	1.6	1952–54
Homogeneous Reactor Test (HRT)	5.0	1957–61
Molten salt		
Aircraft Reactor Experiment (ARE)	2.5	1954–55
Molten Salt Reactor Experiment (MSRE)	7.4	1965–69
Fast burst		
Health Physics Research Reactor (HPRR)		1963–87
Water cooled		
Low-Intensity Test Reactor (LITR)	1.5 (later 3.0)	1950–68
Bulk Shielding Reactor (BSR)	2.0	1950–87
Geneva Conference Reactor	0.1	1955
Tower Shielding Reactor I (TSR-I)	0.5	1954–58
Tower Shielding Reactor II (TSR-II)	1.0	1958–92
Oak Ridge Research Reactor (ORR)	30	1958–87
High Flux Isotope Reactor (HFIR)	100 (now 85)	1965–

Figure 187. Table of reactors built and operated at ORNL, grouped by type. Both the thermal power, in Mw, and the years operated are listed. Note that all reactors in use by 1958 were designed to operate at power levels of 5 Mw or less, excepting the ORR which attained a power level of 30 Mw by 1960 (Rosenthal 2010:8).

Perhaps the most notable safety feature of Building 3042 was its containment. The building featured the unique characteristic of being a semi-airtight building, unlike most reactor buildings that were hermetically sealed. In order to contain gaseous fission products in the event of an accident, a ventilation system exhausted air from Building 3042 at a rate ensuring ground level air leaked into the building rather than out of it. Furthermore, all exhaust air was treated by a scrubbing and filtration system prior to its discharge from the Building 3039 stack. This characteristic resulted from AEC requirements made at the outset of planning for ORR construction, necessitating all "hot" gases were released into the building in the case of an accident. All pedestrian entries to the building exhibited hydraulic door-closing devices and the service entries featured pneumatic devices for automated operation (Binford 1962:1-5).

ORR Experimental Facilities

As a reactor constructed to fulfill drastically expanding experimental needs at ORNL, the facilities provided at the ORR were paramount to its success. Experimental facilities at a research reactor such as the ORR provided access to the radioactive reactor core for research purposes. The Graphite Reactor and LITR offered such facilities in the form of HBs, or ports permitting the insertion of experiments into or near-to the reactor core. The BSR provided access to its core radiation through the open pool. The ORR, however, provided a multitude of experimental facility types. Throughout 1957 the need for the facilities provided by the ORR became increasingly urgent. (Cole and Gill 1957:2). "The need for improved facilities for experiments requiring neutron beams, for expanded isotope production, and for an irradiation facility to permit engineering tests of the materials and components of liquid fuel reactors became increasingly important. Construction and operation of the ORR helped meet the requirements for neutron irradiation space of both the basic and applied research programs of the Laboratory and met the expanding requirements for radioisotope production at ORNL" (Hamrick and Swanks 1968:1).

The ORR originally provided two large engineering test facilities and six HB facilities at the ORR, as well as access to the core through the pool water, providing numerous in-reactor experiment options. "The ORR has four general types of experiment facilities. These include six horizontal beam holes which penetrate the east biological shield and terminated inside the reactor vessel at the core housing; two large engineering facilities, approximately 25 x 19 in., which penetrate to the core housing on the north and south sides; the flat poolside face which permits access to the core region outside the reactor vessel on the west side; and a variable number of in-reactor positions, access to ten of which may be gained through flanges in the reactor tank top" (Figures 188 and 189) (Tabor and Costner 1962: 41). Staff anticipated an extremely varied experiment schedule across multiple ORNL divisions, ranging from the more traditional sample irradiations to the more complicated in-pile loops used to test candidate fluid reactor fuels (Cole and Gill 1957:1, 43–44; Tabor and Costner 1962:2-3). Before the ORR even became operational, the Chemical Technology, Solid State, Isotopes, Chemistry, Analytical Chemistry, Physics, and Health Physics Divisions had all claimed space at these research facilities (Cox and Casto 1958:4).

The six HBs, similar to facilities available at the LITR, were designed for more permanent experiments, such as neutron scattering studies (Figure 190) (Tabor and Costner 1962:41). The Engineering Department designed the engineering test facility on the north side of the reactor structure, known as the North Engineering Test Facility, or North Facility, with input from several ORNL divisions and program groups. This included the ORR Design Group itself as well as the HRE (in regards to loop and rocking bomb experiments), the Chemical Technology Division (in regards to plutonium recovery processes), and the Analytical Chemistry Group (in regards to a pneumatic rabbit tube installation and station). The North Facility equipment, scheduled to be installed by November 1, 1956, was reviewed by the ANP Division in consideration of mimicking the designs for their purposes in the engineering test facility on the south side of the reactor structure, referred to as the South Engineering Test Facility or simply the South Facility (Gill and Cole 1956:7-9). These engineering test facilities on either side of the reactor structure included permanent shielding (Figure 191) (Casto 1959:7). Shielded plugs for these large facilities were also developed for safety reasons and, for convenience purposes, these plugs incorporated several smaller holes to provide facilities for more minor experimentation (George 1962:6-10). Both the North and South Engineering Test Facilities were primarily utilized for in-pile loops, often contributing to the EGCR Program (Tabor and Costner 1962:41–45). In-pile loops were comprised of pipes that travel to or near the reactor core and allow for experiments, particularly those exploring potential reactor fuels, to propel material through the reactor's radiation field in order to measure their performance. By 1961, extensive use of these engineering test facilities led personnel to design a movable personnel and instrument shield for the South Engineering Test Facility in preparation for the installation of a EGCR Program related test loop (Muckenthaler et al. 1961:1-2).

The Poolside Facility, located along the flat side of the reactor tank, directly adjacent to the reactor core, provided the most accessible facility at the ORR (George 1962:10). This facility was generally used for materials-damage studies and, later, gas-cooled capsule studies (Tabor and Costner 1962:45). Also referred to as the Poolside Capsule Facility, this high-flux facility provided ample space for large experiments requiring a high neutron flux density. Such experiments were "irradiated at an infinitely variable radial distance from the core… incident neutron fluxes can be varied from essentially zero to peak values" (Thoms et al. 1984:2). These neutron fluxes were bested only by the in-core facilities discussed below. Due to its location within the pool, experimenters were afforded great visibility and flexibility of movement. This facility eventually served for capsule irradiations, particularly for the EGCR Project discussed further below in the "Additional Reactor Engineering Experiments" section (Trauger 1964:13; Allen and Kerr 1976:26). This facility was particularly ideal for experiments requiring a short duration of irradiation (Thoms et al. 1984:2).

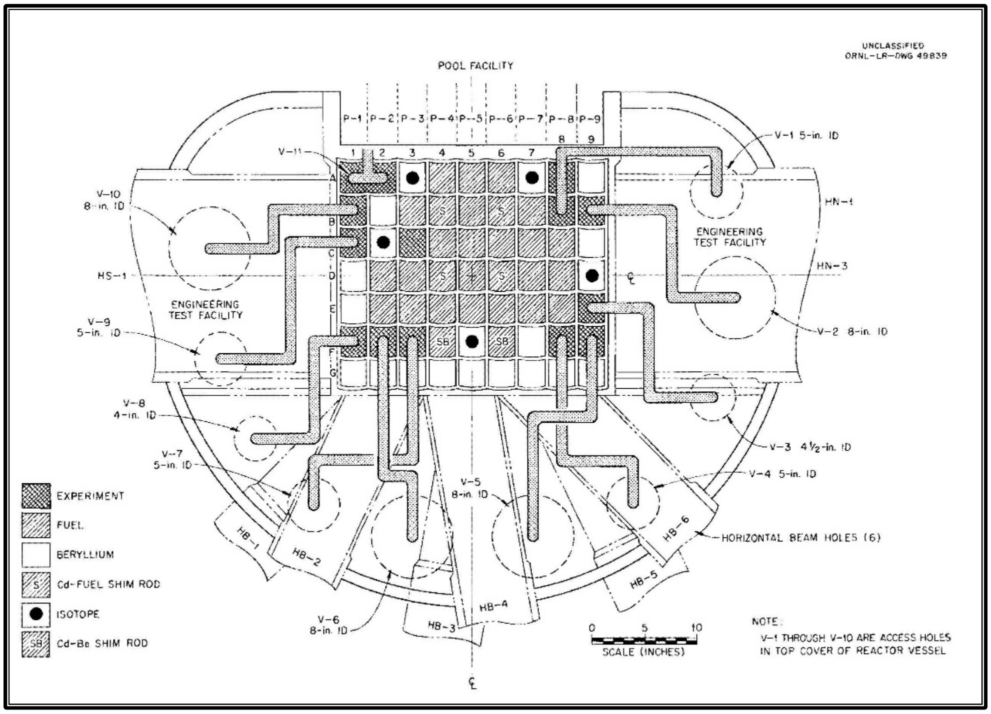


Figure 188. Diagram (ORNL-LR-DWG-49839), circa 1962, showing a horizontal section through the ORR, including the six HB facilities (HB-1 through HB-6), two engineering facilities (referred to as HS and HN), Pool Facility (P-1 through P-9), and in-reactor facilities (V-1 through V-10) (George 1962:8).

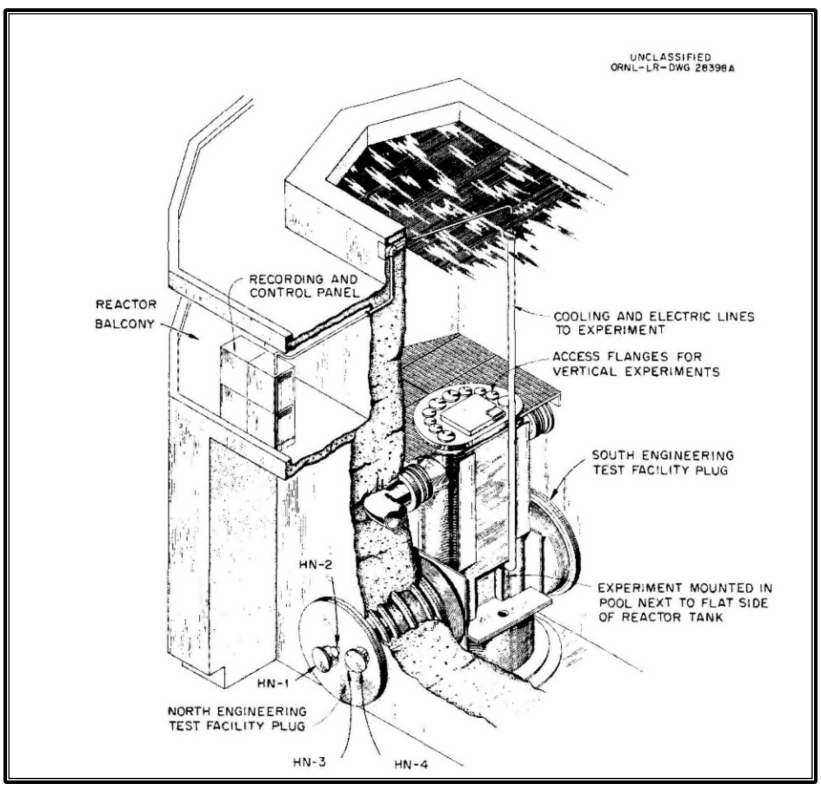


Figure 189. Diagram (ORNL-LR-DWG 28398A) showing a three-dimensional section of the ORR including the North and South Engineering Test Facilities and Poolside Facilities, circa 1962 (George 1962:9).

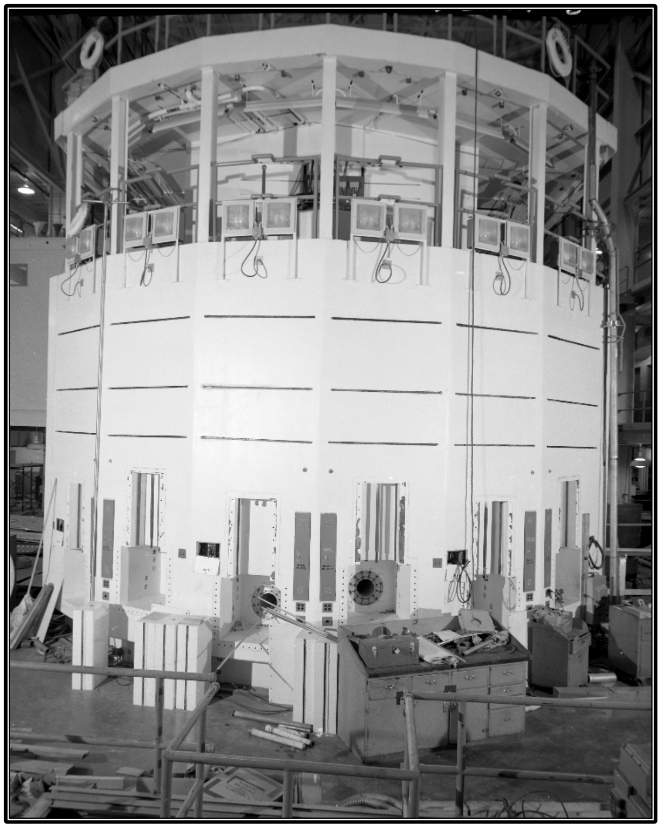


Figure 190. Archival photograph showing most of the HB facilities piercing the face of the reactor structure in Building 3042, circa 1957 (ORNL Photo 42186).

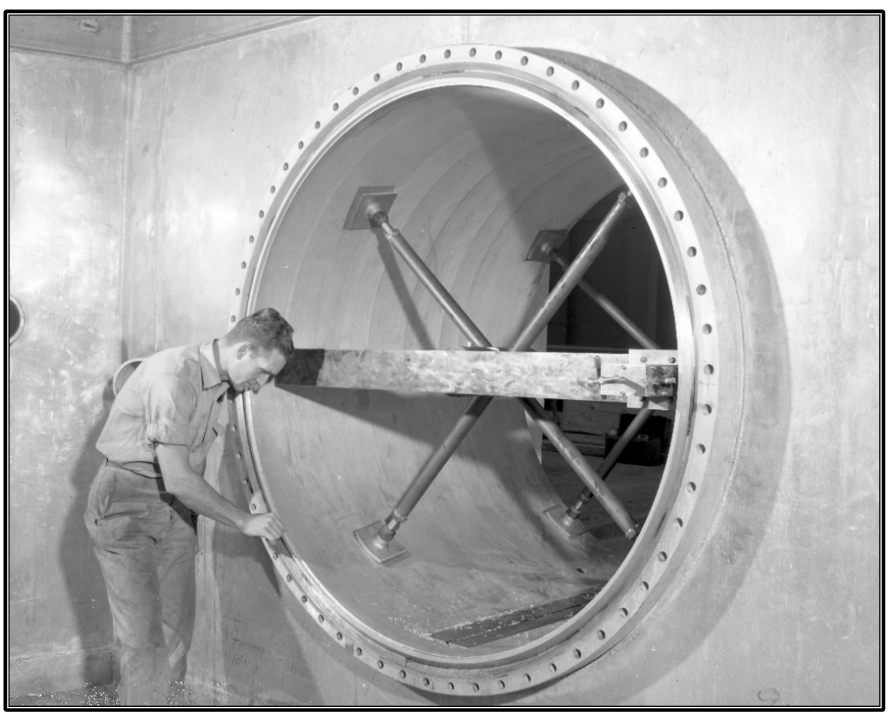


Figure 191. Archival photograph showing the exterior of one of the large engineering test facilities in the ORR while under construction, circa 1957 (ORNL Photo 41688).

The in-reactor experimental facilities, referred to as “in-core” or “lattice positions,” most often served for radioisotope production, fuel studies, and material-damage studies (Tabor and Costner 1962:45). These radiation locations provided the highest neutron fluxes available at the ORR. Access to the in-reactor facilities was through the flanges in the reactor tank top (George 1962:6). Researchers often encased their experimental assembly in aluminum “dummy” core pieces, shaped like fuel elements or control rods, and placed them into the reactor core grid plate (Thoms et al. 1984:2). The hot cells at the west end of the pool both featured a bottom door, allowing the transfer of experiments and irradiated isotopes from the reactor pool into a hot cell for shielded inspection shortly after irradiation (Tabor and Costner 1962:2; Trauger 1964:4).

ORNL began utilizing in-pile loops at several reactors in the late 1950s. At the ORR, three loops were constructed, each derived for testing particular reactor designs. Two of these loops were the result of the EGCR Project and the third simulated a pressurized-water reactor system. The ORR Gas-Cooled Loop No. 1, completed by 1962 and also referred to as the GCR-ORR Loop No. 1, circulated helium gas in order to test clad fuel elements for use in the EGCR Program. The majority of the loop was located within the pool itself, but some of its auxiliary equipment were placed in a shielded cubicle on the lower reactor structure balcony. The second gas-cooled loop, or GCR-ORR Loop No. 2, allowed for irradiation of unclad fuel elements. Connected to the south beam hole of the ORR, all equipment for this loop was located inside a shielded cell near the pool wall. The use of both of these loops are discussed further below, in the “Additional Reactor Engineering Experiments” section (Trauger 1964:36, 42, 49–50). The third loop at the ORR, referred to as the Pressurized-Water Loop, facilitated reactor engineering experimentation, particularly in regards to the Maritime Reactor Program, discussed further below in the “Maritime Reactor Project” section. This loop, completed in 1959, traveled within the pool and accessed the core vertically through the reactor vessel (Trauger 1964:57).

By 1962, the ORR offered two additional experiment facilities: a hydraulic tube facility and a pneumatic tube facility. The hydraulic tube facility was comprised of four sample tubes connecting a loading station in the pool to the reactor lattice. Aluminum sample containers, referred to as “rabbits,” were loaded in the tubes and subjected to both radiation in the reactor core as well as cooling water sent through the tubes (Figure 192). The pneumatic tube facility also accommodated rabbits, this time comprised of high-density polyethylene plastic. These samples were irradiated in the reactor core while cooled by forced air, rather than water. Rabbits were loaded into the pneumatic tube facility in a hood located in the basement and completed their trip to the reactor core in three seconds or less (George 1962:10–13).

Another facility, specifically for fuel-irradiation tests, was added to the reactor core sometime before 1964. Referred to as the ORR Eight-Ball Capsule, this facility provided needed space for high fast-neutron flux experiments involving coated-particle spherical fuel elements comprised of graphite (Trauger 1964:27). Loops and capsules, both frequently used in reactor design and fuel research, were seemingly similar technologies. “The two classifications, capsules and loops, employed in describing irradiation test equipment are distinguished by the method of heat transfer from the fuel surface. In capsules, heat transfer is principally by conduction, whereas loops employ convection cooling, usually by a recirculating coolant forced by pumps or compressors. By their simplicity, capsule facilities are less costly to construct and operate, but they do not simulate the reactor service as realistically as loops” (Trauger 1964:5).

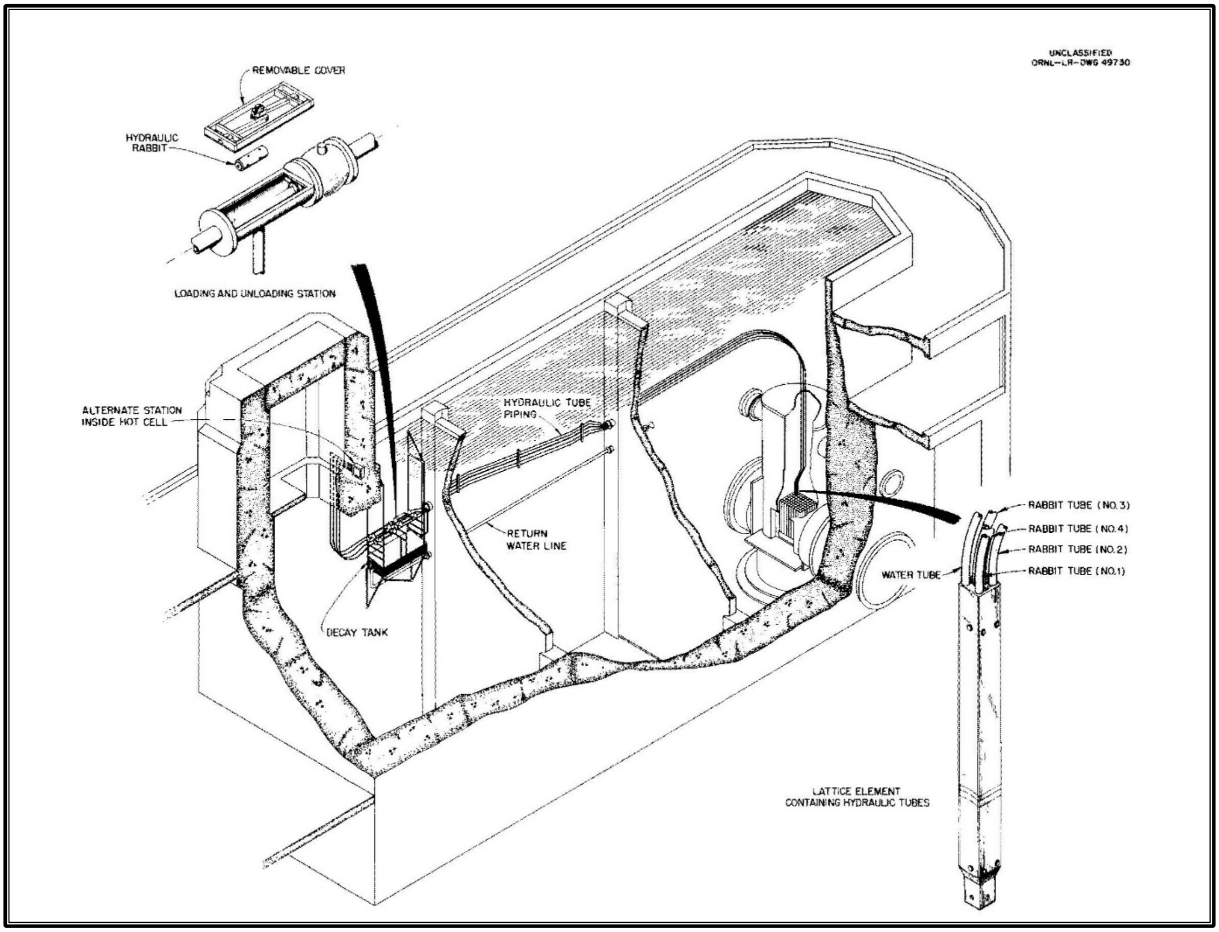


Figure 192. Diagram (ORNL-LR-DWG 49730) showing the ORR hydraulic tube facility, referred to as the hydraulic rabbit system, circa 1962 (George 1962:11).

Research Programs at the ORR

Building 3042 hosted a multitude of programs and experiments utilizing the many research facilities and high-flux of the ORR. While impossible to cover every experiment or research program in a single document, the most significant ORNL programs intrinsically related to work at the ORR are discussed individually below.

The IDP and the Centralization of Radioisotope Production at ORNL

After World War II, the mission at Clinton Laboratories, now ORNL, shifted away from the research efforts involved with the then-completed Manhattan Project. In 1946, the newly formed AEC, which oversaw the peacetime development of nuclear science, directed Clinton Laboratories to focus on three fields: basic research, chemical technology, and isotope production and research (Carver and Slater 1994:90). Prior to the war, cyclotrons at other locations, similar to 86-inch Cyclotrons constructed at the Y-12 complex during the war, produced several different types of radioisotopes in small quantities. The limited quantities, coupled with prohibitive prices, restricted the accessibility of radioisotopes to researchers, restraining their research potential. A reactor pile, such as the X-10 pile that came to be known as the Graphite Reactor after the war, possessed the potential to generate far larger quantities of radioisotopes at a lower cost, greatly expanding the scope of radioisotope research (Hadden 1948:3.1; McCullough and McCullough 1992:18).

Arthur Rupp, one of the founders of the IDP at ORNL, remembered that a handful of ORNL chemists "were very interested in the possibility of merchandizing, or distributing, radioisotopes to various labs around the country that needed them. And, there were many chemists, all around the country, who were interested in a possible radioisotope production program… an ill-formed group of just a few people from what was then the Operations Division, the Chemistry Division, and the Physics Division made in a not-too-well-organized way a few of the most important isotopes for distribution" (Rupp and Gillette 2003:10). Thus, in accordance with their new mission, the Radioisotope Committee of Clinton Laboratories presented a proposal on January 3, 1946, for the national distribution of reactor-produced radioisotopes for both general and cancer research. Dr. Paul C. Aebersold became chief of the Isotopes Branch within the Research Division. His experience consisted of nuclear physics applications in biology and medicine as well as early cyclotron radioisotope production. The Isotopes Branch began operation in February 1946, with Aebersold leading the establishment of off-site radioisotope distribution. On June 14, the AEC made the public announcement in *Science* journal, including a list of approximately 100 isotopes available for purchase for scientific and medical research purposes (Hadden 1948: 3.1–3.11). This action was considered "one of the most significant peacetime results of the nation's great investment in nuclear fission" (Hadden 1948:3.2).

On August 2, 1946, the first radioisotope shipment was made under the IDP initiated by the Manhattan Engineer District (Figure 193). This shipment consisted of one millicurie of carbon-14, equal to "an amount of material in which there are… 37 million disintegrations per second," to the Barnard Free Skin and Cancer Hospital in St. Louis, Missouri (Thompson 1952:14, 17). Arthur Rupp described carbon-14 as "one of the most important of all the radioisotopes we have, because it is used in tracing biological and medical processes" (Rupp and Gillette 2003:10). The hospital purchased the carbon-14 in order "to 'tag' component parts of cancer producing molecules and then, through radiation measuring instruments, seek an answer to this question: 'Why does this particular molecule produce cancer?'" (Hadden 1948:3.20).

Shortly after this initial shipment, Clinton Laboratories established the Isotopes Section in 1947 (Johnson and Schaffer 1992b:37). The demand for radioisotopes grew quickly, and in July 1947, ORNL celebrated the 1000th shipment of a radioisotope (Figure 194). On March 1, 1948, Carbide and Carbon Chemicals Company (later Union Carbide), a division of Union Carbide and Carbon Corporation, assumed operation of X-10 and the AEC renamed Clinton Laboratories to ORNL (Thompson 1952:5-6).

Between August 1946, when the first reactor-produced radioisotope was distributed from Oak Ridge, and January 1950, the number of monthly isotopes shipments increased tenfold (Carver and Slater 1994:102). The AEC's Advisory Committee on Biology and Medicine stated in 1948 that "the availability of radioisotopes is contributing more than any other factor today to the advancement of medicine and biology" (Thompson 1952:16). In the 1950s, ORNL was the principal producer and distributor of both radioactive and stable isotopes in the country. Between the outset of the radioisotope-distribution program in 1946 and 1952, the purified radioisotopes available in routine production expanded from 3 to about 40 and the production rate more than doubled. This expansion reflected the rapidly increasing demand for radioisotopes after the war (Thompson 1952:12). During the first quarter of 1950, just over 50 percent of the domestic shipments to users outside the AEC were distributed for cancer-related work, with production fees waived (Murray et al. 1950:53).

Figure 193. Archival photograph of Eugene Wigner, ORNL Research Director (third from right) handing the first reactor-produced radioisotope shipment to Dr. E. V. Cowdry, Research Director of the Barnard Free Skin and Cancer Hospital of St. Louis, Missouri (second from right) circa August 1946 (ORNL Photo 238).

Figure 194. Archival photograph of ORNL employees loading the 1000th radioisotopes shipment onto a truck circa July 1947 (ORNL Photo 8.psd).

At this time, radioisotopes were ordered for medical, biological, industrial, and agricultural research as well as for the treatment of certain diseases both domestically and abroad. Radioisotopes were also used for research in chemistry, physics, plant physiology, and animal husbandry metabolic studies. These uses depended upon the radioactive quality of radioisotopes. Firstly, radioactive atoms could be detected and therefore "counted," which enabled experiments that trace atomic changes and movement in various materials. Secondly, many types of matter exhibited prominent impacts from exposure to radiation. Biological and medical research uses for radioisotopes were the most publicized, particularly radioisotope use in cancer research and treatment (Thompson 1952:26-29). The earliest radioisotopes of medical importance included the radioactive isotopes of carbon, phosphorous, and iodine. Carbon-14, the first radioisotope shipped by ORNL, could be used as a tracer for following chemical reactions or nutrients and pharmaceuticals, as these short-lived radioactive tracers emit gamma rays from within the body which can then be detected and measured. Phosphorus-32 is used in DNA analysis as well as to treat leukemia and ovarian cancer, and iodine-131 is used in thyroid cancer therapy as well as to generally study the thyroid gland (Rupp and Gillette 2003:11; Ginsberg 2008). By 1958, the year the ORR became operational, over 1,700 physicians and medical institutions were utilizing radioisotopes for medical purposes (Aebersold and Hutton 1958:2). The AEC estimated in their semiannual report for January–June of 1957 that radioisotopes production and sales had contributed $400 million per year to the national economy (Figures 195–197) (Roth 1958:1).

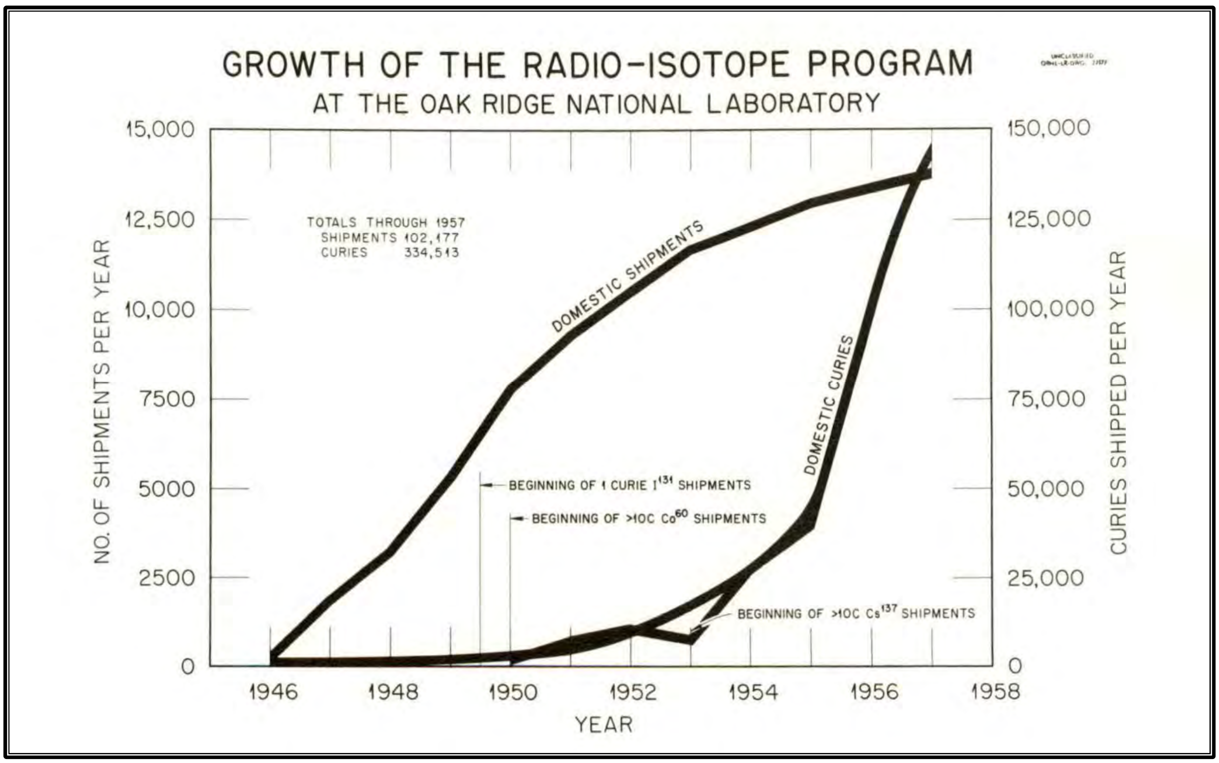


Figure 195. Chart titled "Growth of the Radio-Isotope Program" at the ORNL indicating substantial growth both in terms of the domestic shipments and the number of curies shipped per year from 1946 through 1958 (ORNL-LR-DWG 27177) (Roth 1958:1).

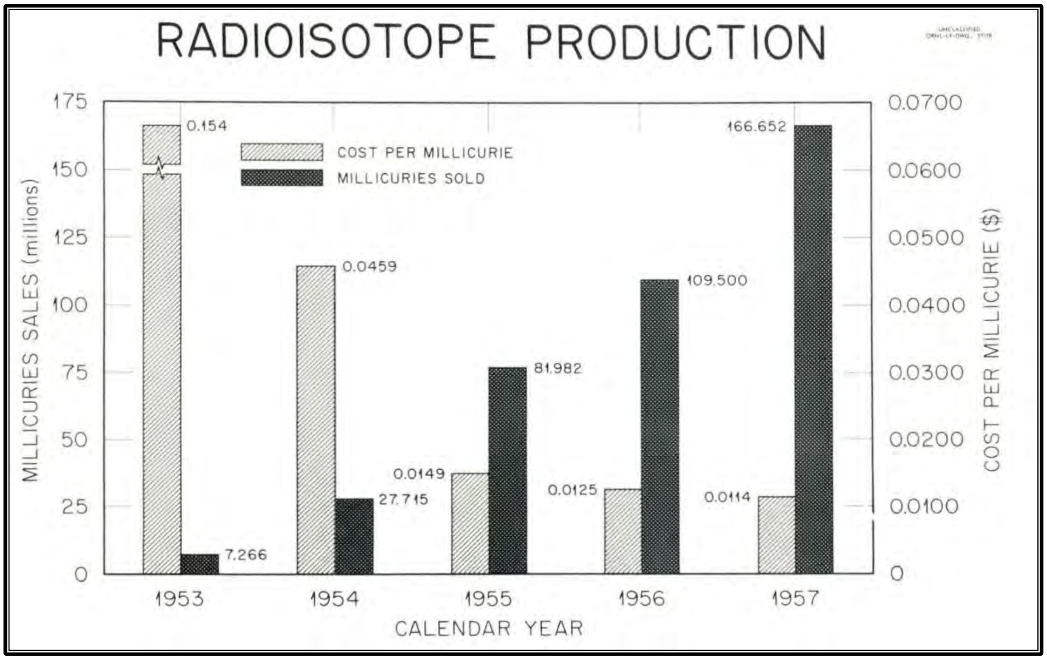


Figure 196. Chart titled "Radioisotope Production" indicating the indirect relationship between millicuries sold and the cost per millicurie due to the radioisotope-processing improvements through the 1950s. The costs are calculated by the out-of-pocket production cost, excluding overhead (ORNL-LR-DWG 27178) (Roth 1958:2).

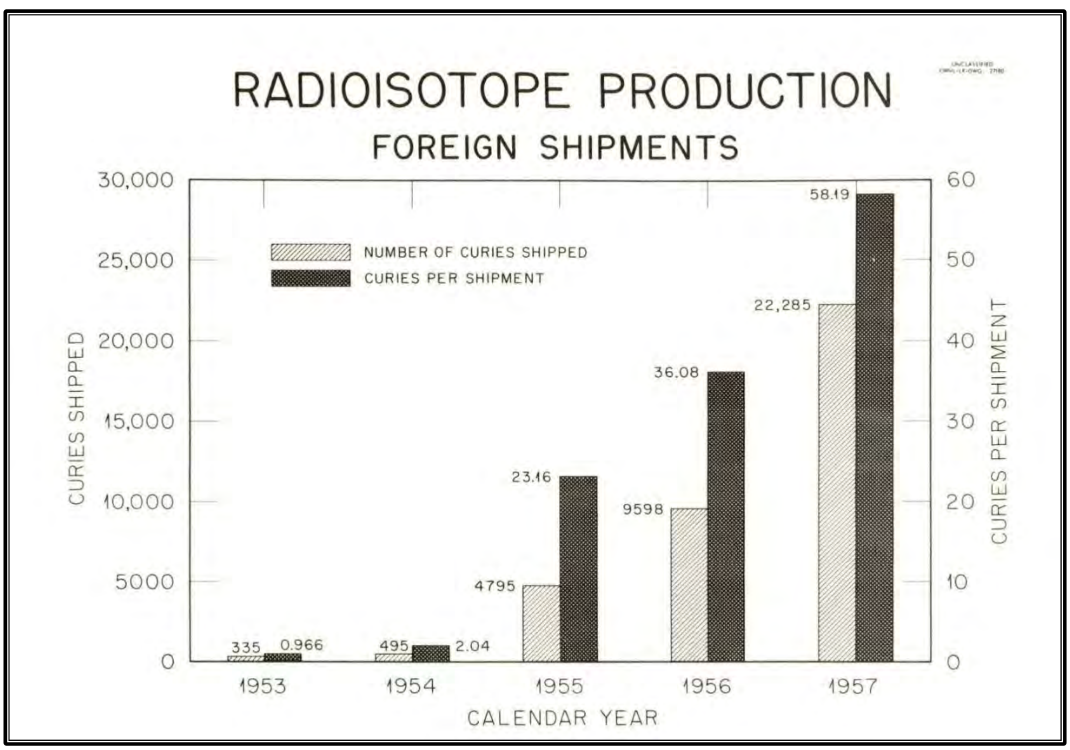


Figure 197. Chart titled "Radioisotope Production: Foreign Shipments" indicating the increasing number of shipments to foreign countries through the 1950s, despite the construction of nuclear reactors overseas inferring that specialized radioisotope-processing facilities were also required for a complete radioisotope program (ORNL-LR-DWG 27180) (Roth 1958:3).

In response to this overwhelming growth, the initial proposal for what would become the ORR referred to the requested reactor as a "Research and Isotope Reactor" (Snell and Weinberg 1950). By linking the desired high-flux reactor to the IDP, they likely accelerated the AEC's approval, which had hitherto been hesitant due to the safety concerns inherent in the erection of a high-power, high-flux reactor in closer proximity to human populations than any prior similar installation, such as the MTR in Idaho. The growth of the IDP consistently outpaced the available production facilities through the early 1950s. In 1953, the increasing demand for radioisotope production inspired ORNL staff to propose raising the power level of the LITR. In the interest of efficient use of existing facilities, ORNL requested permission from the AEC for experimental operations at 3000 kw, or 3 Mw (Cole 1953:1-3). This proposal succeeded on September 2, 1953 and the LITR officially became a general research facility (Cagle and Casto 1968:1-2). Earlier that same year, the AEC approved moving forward with ORR design and construction.

By the mid-1950s, the LITR began supplying many of the radioisotopes shipped from ORNL. Within a typical six-week irradiation timeframe, the LITR was found capable of producing approximately 300 times more phosphorus-32 radioisotope product per gram of sulfur than previously possible in the Graphite Reactor. The Operations Division theorized in their 1955 "Radioisotope Production and Process Development Annual Report" that the ORR would produce even better yields (Rupp 1956:4-5). Further studies reported in the 1956 "Radioisotope Production and Process Development Annual Report" provided more concrete estimates: "A method was developed in which irradiated sulfur was distilled, leaving [phosphorus-32] with sufficient purity to be dissolved as a product. This procedure has been made feasible by the availability of higher flux densities in the LITR. The ORR will provide even greater flux densities. It is anticipated that 5 to 10 g of sulfur irradiated in the ORR will produce the same quantity of [phosphorus-32] as will be produced by 10,000 g irradiated in the ORNL Graphite Reactor" (Seagren 1957:5). As the completion of the ORR began to appear on the horizon, ORNL organized the Isotopes Division on May 1, 1957 to "consolidate into one group the development, the production, and distribution functions of the radioisotope and stable isotope programs" (Seagren 1958:1).

Broadly speaking, reactors were not designed explicitly for radioisotope production, rather, space became repurposed for this function as demand grew. Within the AEC's purview, space was originally obtained at the ORNL Graphite Reactor and later the Hanford Reactors, the LITR, the MTR, and the Savannah River Site reactors. Top priority at these reactors, however, never officially shifted to the radioisotope program. The ORR was no different as ORNL intended it to serve principally for reactor engineering experiments and physical research. Nonetheless, with ORR construction underway, ORNL was poised to "have available (at the principal radioisotope production site) the high flux needed for present-day radioisotope production" (Roth 1958:24). From the inception of the ORR, it was assumed that radioisotope production would embody a significant portion of operations and, after completion in 1958, "the ORR's unique research and production features allowed it to produce the isotopes needed for research, medicine, and industry faster, more economically, and in greater quantities than any other reactor anywhere at that time" (Figure 198) (Stapleton 1993:31; Cole and Gill 1957:44).

Through the 1960s, as uses for radioisotopes continued to evolve and diversify, the Radioisotope Applied Research Program, within the Isotopes Division, developed, assessed, and improved their techniques, production methods, and radioisotope quality assessments in order to fulfill the demands for both current and new products (Gillette 1966:1). These investigations considered all of the ORNL irradiation facilities, analyzing the most cost-effective and efficient facilities to use per each specific need. The ORR was determined in 1962 to be the best facility for use in regards to generating radioisotopes of high-specific-activity, considering the high neutron flux (George 1962:21-22). Strict requests for radioisotopes exhibiting high specific activity, purity, and special radiation properties, such as a specific half-life, typically originated from the medical and biological fields. In 1963, ORNL considered installing a loop in the ORR for regular iodine-125 production (Baker et al. 1963:46-47).

Figure 198. Archival photograph showing an ORR Isotope Irradiation Assembly, circa 1957. Isotope cans were inserted into the cylindrical chambers prior to the assembly being inserted into the ORR for irradiation (ORNL Photo 41741) (Neumann 1961:6).

These comprehensive studies also led the Isotopes Division to measure the neutron flux patterns of the various irradiation facilities at both the ORR and LITR in 1965. While operating the ORR at full reactor power, they irradiated monitor specimens comprising both natural iron and stainless steel wires and calculated the fast neutron flux values based on the manganese-54 yields and the thermal neutron flux values based on the cobalt-60 yields. "The magnitude of the neutron flux and the ratio of the fast-to-thermal neutrons must be known in order to select the optimum position for irradiation and to interpret the results. These data represent the first compilation of fast neutron fluxes for these facilities" (Gillette 1966:1). Also in 1965, ORNL completed the construction of the HFIR, which would contribute to their radioisotope production (see Figure 179).

Also in the 1960s, ORNL became involved with the Surveyor mission, a NASA program aimed at landing instruments on the moon's surface prior to the Apollo mission. NASA chose Curium-242, which was considered relatively easy to shield and to have a high power density, as an isotopic fuel utilized on the Surveyor spacecraft. At that time, the production capacity for Curiuim-242 resulted in milligram quantities; however, the Surveyor mission would demand tens of grams annually. To solve this problem and potentially raise the Curium-242 production capacity to 80 grams annually, ORNL "is now completing the installation of facilities for the production of Americium 241 targets, the solvent extraction separation of Americium 241 – Curium 242 fraction from the fission products, and the fabrication of thermal sources. Americium 241 will be pelletized, encapsulated, and irradiated in a high-flux reactor such as the Oak Ridge Research Reactor or the Materials Testing Reactor… The irradiated material will be dissolved and the fission products removed by solvent extraction… The final solution will be further processed into a Curium 242 oxide, which will be calcined, pelletized, sintered, doubly encapsulated, welded, and leak checked" (Baker et al. 1963:52–53).

While ORNL blazed the trail and streamlined the process with such efforts throughout the 1950s and 1960s, the AEC never intended to maintain a monopoly on the isotope market. In 1963 W. E. Thompson noted that "a fairly large private industry has been built up, depending upon the radioisotopes produced at ORNL" (Thompson 1963:172). The AEC radioisotope business possessed a rather unique policy of self-termination. This policy, implemented in the 1950s, indicated that the AEC would withdraw from radioisotope production once they became available through private industry. In the beginning, the AEC was uniquely capable of producing radioisotopes due to the rarity of nuclear reactors, however, by the 1960s reactors had multiplied. On March 2, 1965, the AEC reaffirmed their policy to transfer commercial production and distribution of radioisotopes to private industry as quickly as possible. Furthermore, private groups could formally request that the AEC cease production and distribution of particular radioisotopes (Stason 1967:387). Inevitably, isotopes with the potential for generating a profit were pursued by private industry, leaving the DOE to produce isotopes of questionable economic viability.

ORNL eventually stopped making bulk radioactive material shipments of radioisotopes, like carbon-14, phosporus-32, and iodine-131, to the large radiopharmaceutical and product companies, such as Mallinckrodt in St. Louis and the New England Nuclear in Boston, but continued work on isotopes that private industry lacked interest in due to the high production costs (Krause 1986:79). This included heavy elements and others (Table 1). The production of radioisotopes at ORNL waned through the 1980s as private industry and government-related organizations outside the U.S. provided the majority of isotopes for the multi-billion-dollar isotope economy. It was estimated in 1988 that the isotopes needed to support this industry totaled an annual value of $500 million and that the DOE IDPs, predominantly housed at ORNL, provided approximately three percent of that amount, predominately consisting of those isotopes that would not otherwise be available due to the high cost of production. While in the late 1980s the DOE continued to provide more than 300 various stable and radioactive isotopic materials, the DOE was the sole source (with little exception) of five high-specific-activity radioisotopes as well as the radioactive "heavy elements" (see Table 1; Figure 199) (Ottinger et al. 1988:vi–vii). After the DOE placed all nuclear reactor activities on hold in 1987, the ORR would never be brought back online and the HFIR would continue as the sole ORNL supplier of these isotope products.

Table 1. Radioisotopes for which ORNL had a unique production capability, data circa 1988 (Ottinger et al. 1988:vii).

Radioisotope (Abbreviation)	Use	Availability as of 1988
High-specific-activity (HSA) Cobalt-60 (60Co)	Cancer treatment	DOE only
Caesium-137 (137Cs)	Cancer treatment	DOE only
Strontium (90Sr)	Remote power applications; source of Yttrium-90 (90Y); cancer treatment	DOE only
Krypton-85 (85Kr)	National defense; quality control	DOE, USSR
Tritium, or Hydrogen-3	Remote nonelectrical lighting systems	DOE only
Heavy elements (various)	Research and nuclear surveillance purposes; cancer therapy and national defense applications (specifically Californium-252)	DOE only, except: 241Am – DOE, France

Radioactive

Al-26	Cs-137	In-114	Pu-236	Se-75	Ti-44
Am-241	Co-60	I-123	Pu-237	Si-32	U-233
Am-243	Cu-67	I-129	Pu-238	Na-22	U-234
Ar-37	Cm-244	Ir-192	Pu-239	Sr-82	U-235
Ba-135m	Cm-248	Fe-52	Pu-240	Sr-85	U-236
Bk-249	Eu-152	Fe-55	Pu-242	Sr-90	U-238
Be-7	Gd-153	Kr-85	Pa-231	Tc-99	V-48
Br-77	Ge-68	Mg-28	Rb-83	Th-229	Xe-127
Cd-109	Hf-172	Np-237	Ru-97	Th-230	Y-88
Ca-41	Nf-181	Ni-63	Sm-151	Sn-113	Y-90
Ca-249	H-3	P-33	Se-72	Sn-119m	Zn-69m
Ca-252					

Figure 199. List of radioisotopes routinely provided by ORNL as of 1988 (Ottinger 1988:41).

Advancing Neutron Science

The most notable characteristic of the ORR at the time it achieved criticality was the intense neutron fluxes that the reactor offered ORNL scientists. This attribute not only contributed to expanding the radioisotope production rate as discussed above, but significantly broadened the research and experimentation potential at ORNL. One of the most influential research programs that greatly benefited from the availability of the higher neutron fluxes at the ORR was the Neutron Scattering Program, which began under the Physics Division in the 1940s and transferred to the Solid State Division in the 1960s.

British scientist James Chadwick discovered the neutron in 1932, but it was not until the construction of nuclear reactors, and thusly the availability of intense neutron beams, that neutron scattering research would thrive. “Neutrons are one of two particles found within an atom’s nucleus (the other being protons). When neutrons pass through a sample—of an electrical component, a material or a collection of cells, for instance—they scatter much like balls in a microscopic game of pool. By measuring the energies and angles of the scattered neutrons, scientists can glean details about the fundamental nature of materials that cannot be obtained with other techniques” (Williams 2018:61). Neutron scattering experimentation began at both ORNL and ANL, initially utilizing single-axis instruments to make cross-section measurements on monoenergetic neutron beams, or those exhibiting a narrow range of energies (Figure 200). Soon afterwards, scientists began double-scattering experiments “in which monoenergetic neutrons from one crystal were scattered from a second crystal to obtain information on the coherent scattering characteristics of particular atoms” (Wilkinson 1985:2).

Like many research programs at ORNL, the Neutron Scattering Program began at the Graphite Reactor. Ernest Wollan, who witnessed both the first man-made self-sustaining nuclear chain reaction in Chicago in 1942 and the Graphite Reactor going critical in 1943, joined X-10 (now ORNL) while the installation operated under the top-secret Manhattan Project. Originally, Manhattan Project scientists used the monoenergetic neutron beams of the Graphite Reactor, referred to at that time as the X-10 pile, to measure the neutron cross-sections of uranium-235 and plutonium-239, both fissile materials, to determine the amount of material necessary to create a fission device, or a bomb. Due to his experience in x-ray scattering, Wollan saw another potential use of the world’s first operating nuclear reactor: neutron diffraction, also known as elastic neutron scattering. Similar to x-ray technology, neutrons could be used to peer inside materials at the atomic scale. Neutrons are electrically neutral, and therefore can be used to penetrate a material where they bounce off of atoms making patterns that provide information as to the materials structure, properties, and behaviors (DOE Office of Science 2016).

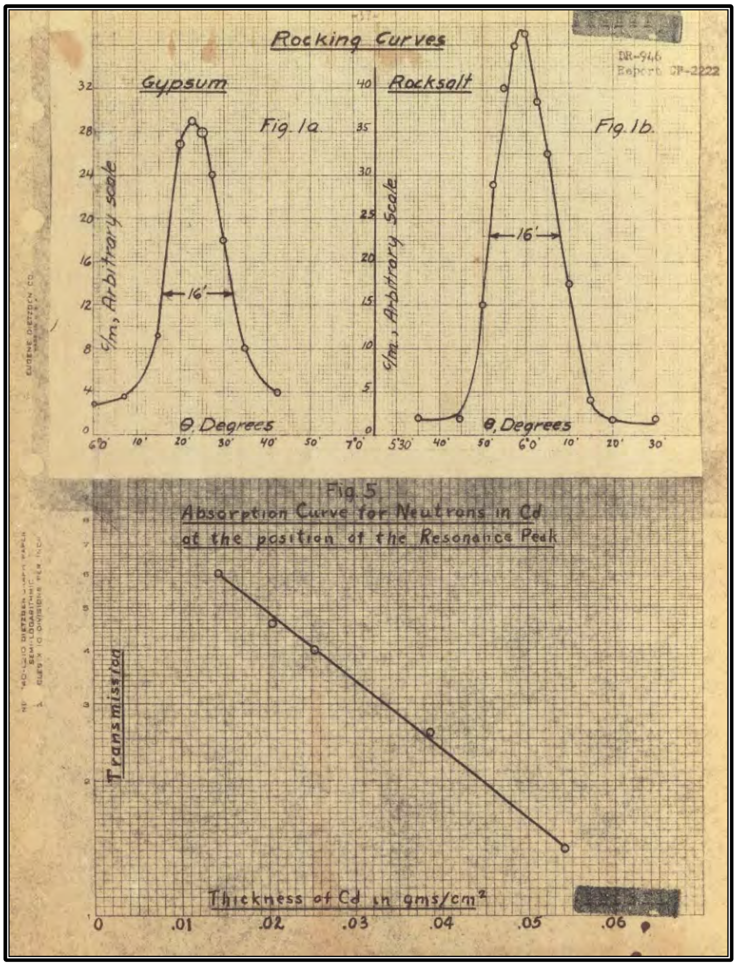
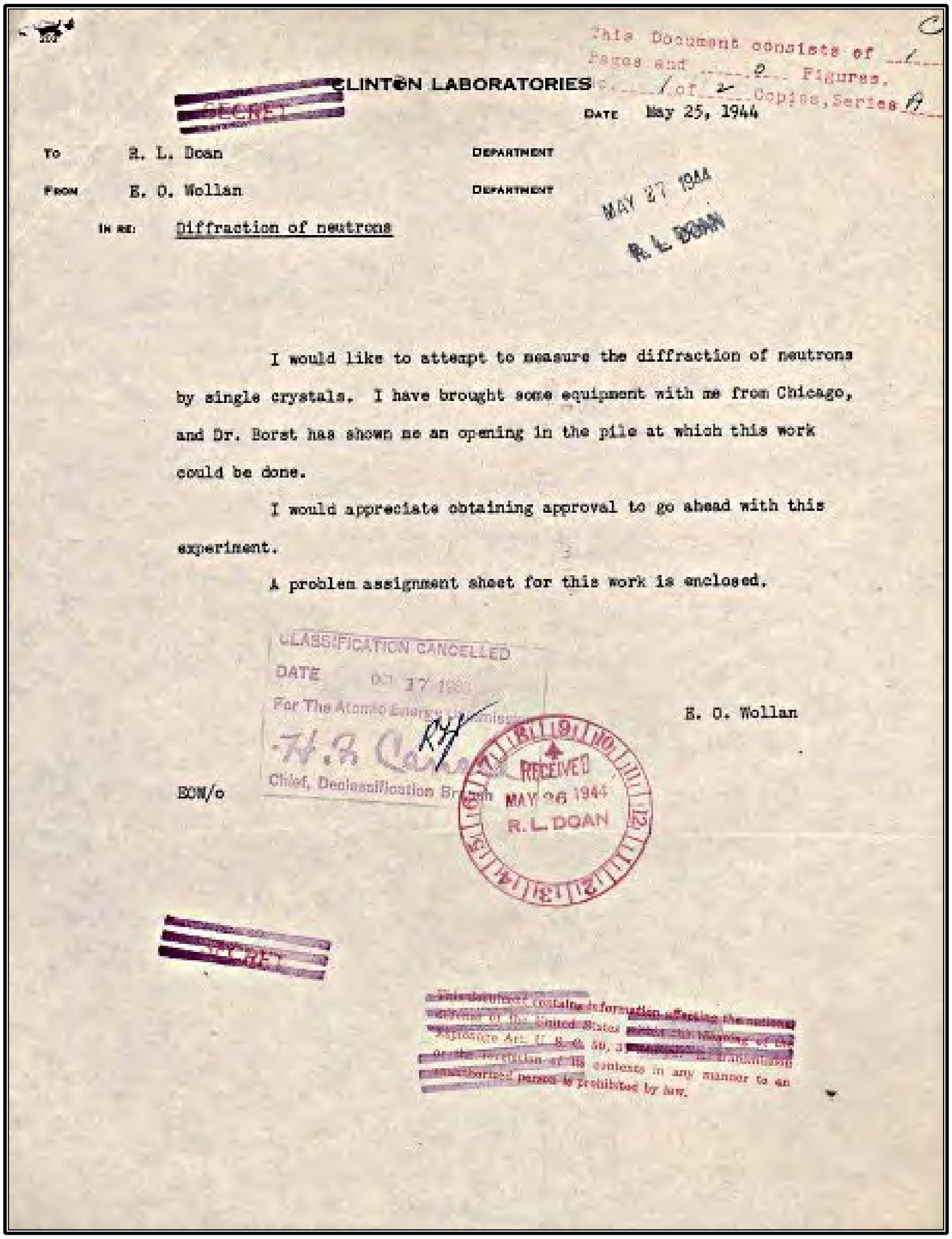


Figure 200. Archival drawing by Ernest Wollan (DR-946 taken from report CP-2222) depicting graphically the research data obtained by the first observation of Bragg reflections of single crystals through neutron diffraction, or elastic neutron scattering, at the Graphite Reactor, circa 1944.

Wollan requested funding for neutron diffraction research in May of 1944, referencing a potential location at the Graphite Reactor (referred to within as "the pile") for this work to be conducted. In his letter, Wollan states "I would like to attempt to measure the diffraction of neutrons by single crystals. I have brought some equipment with me from Chicago" (Figure 201) (Wollan 1944). ORNL staff have long maintained the legend that Wollan "left Chicago in the dark of night" with this equipment in tow (Rumsey 2018). Nevertheless, Clinton Laboratories (now ORNL) accepted this proposal and installed the two-axis x-ray diffractometer, modified at the ORNL shops for use in neutron research, at a Graphite Reactor beam hole in November 1945. This was the very first instrument utilized for neutron diffraction work (Figure 202). Wollan used this equipment to investigate the neutron scattering in multiple materials when exposed to a neutron beam emanating from the reactor and recorded the first powder diffraction measurements made using neutrons. With x-ray scattering, calculations could determine the scattering power; however, neutron scattering required experimental measurements (Wilkinson 1985:2–3; Rumsey 2018; Johnson and Schaffer 1992f:230–231). Wollan "produced a single-wavelength neutron beam by passing reactor neutrons through a crystal and used a spectrometer to measure the angles and energies at which neutrons are scattered by interacting with the nuclei of atoms in the target material. This information helped reveal material structure" (Krause 2003:8).



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[redacted]

CLINTON LABORATORIES

DATE May 25, 1944

TO R. L. Doan DEPARTMENT

FROM E. O. Wollan DEPARTMENT

IN RE: Diffraction of neutrons

MAY 27 1944
R. L. DOAN

I would like to attempt to measure the diffraction of neutrons by single crystals. I have brought some equipment with me from Chicago, and Dr. Borst has shown me an opening in the pile at which this work could be done.

I would appreciate obtaining approval to go ahead with this experiment.

A problem assignment sheet for this work is enclosed.

CLASSIFICATION CANCELLED
DATE OCT 17 19..
For The Atomic Energy Commission
H. R. Carroll
Chief, Declassification Branch

E. O. Wollan

EOW/o

RECEIVED MAY 26 1944 R. L. DOAN

[redacted]

[redacted] contains information affecting the national defense of the United States within the meaning of the Espionage Act, U. S. C. 50, 3[redacted] or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

Figure 201. Copy of the original letter written by Wollan to Richard Doan, Director of Research at Clinton Laboratories (now ORNL), seeking funding for neutron diffraction research at "the pile," now known as the Graphite Reactor, on May 25, 1944 (Rumsey 2018).

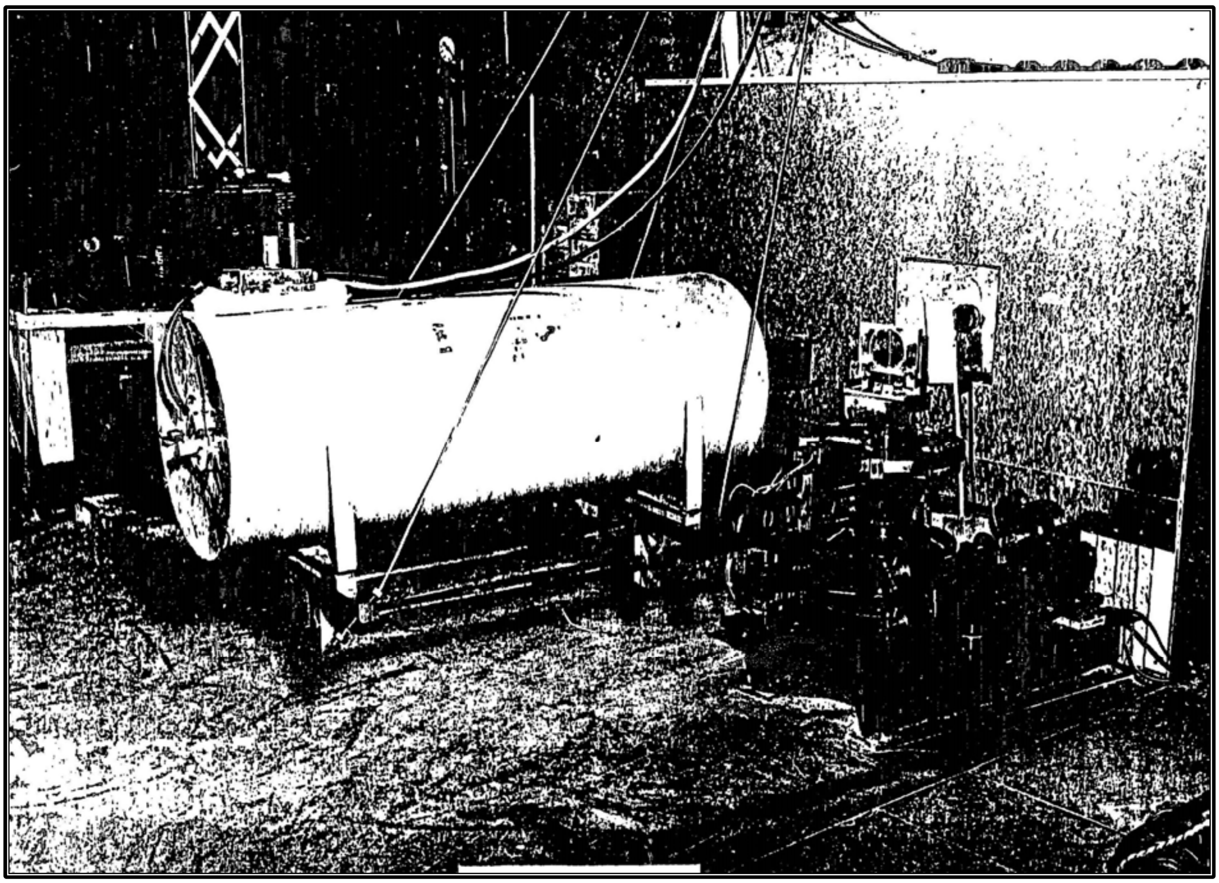

Figure 202. Archival photograph of the modified two-axis x-ray diffractometer installed at the Graphite Reactor in 1945. This photograph was taken after several alterations had been made, circa 1948 (Wilkinson 1985).

After these initial achievements, Clifford Shull, also of the Physics Division, joined Wollan in this research in 1946, thusly creating what would become the Neutron Scattering Program. Their early experiments formed the foundation for elastic neutron scattering that later led to research techniques and equipment used to determine atomic structures and magnetic properties in crystals, solid-state physics, and materials sciences both at ORNL and around the world (Johnson and Schaffer 1992b:50, 1992f:230–231; Wilkinson et al. 2003:3–4; Cabage 2018:13). Michael Wilkinson, who joined Wollan and Shull in their research in 1950, summarized in laymen's terms: "the purpose of neutron scattering is that it is one of the best techniques available for studying the properties of materials and characterizing materials. If you want new materials in any technology you need, you've got to actually be able to study and characterize the new materials properly. Neutron scattering is one of the best techniques you can use. It has made a tremendous impact not only in physics and chemistry, but also in biology and various types of engineering polymers and medical problems. It's just a tremendous technique" (Wilkinson et al. 2003:4).

In 1948 Wollan and Shull, along with junior physicist Milton Marney, made history as the first scientists to measure and photograph neutron Laue diffraction patterns – or regularly spaced spots – in single crystals, using sodium chloride at the Graphite Reactor. Using Scotch tape to combine numerous strips of indium, this also created the first neutron radiographic image (Figures 203 and 204) (Cabage 2018:13; Rumsey 2018).

Motivated by the success of Wollan and Shull's collaboration, ORNL fabricated the world's first two-axis neutron diffractometer designed exclusively for neutron scattering experimentation in the ORNL shops, also known as a double-crystal neutron spectrometer. They installed this instrument at a Graphite Reactor beam port, next to the aforementioned modified two-axis x-ray diffractometer, in July 1950 (Figure 205). As described by Wilkinson, "[t]his diffractometer was a very flexible instrument, and it was the first to use a rotating-drum shield around the monochromating crystal, so that neutron wavelengths could be adjusted continuously. The instrument was also sufficiently sturdy that it could support the detector and detector shield as well as auxiliary apparatus, such as magnets and cryostats, for changing the sample environment" (Wilkinson 1985:3).

Due to their great accomplishments in using neutron scattering to investigate the magnetic properties of materials in the late 1940s, Wollan and Shull continued to focus on such problems through the early 1950s (Wilkinson 1985:16–17). Neutrons have a magnetic moment and therefore provide an ideal method for studying magnetic materials, like those often used in electronic devices. The early Neutron Scattering Program team had also successfully measured the neutron scattering patterns from over 100 elements and 60 isotopes by 1955 (Rumsey 2018).

With the addition of the ORR to ORNL in 1958, the Neutron Scattering Program group gained the best neutron source intensity available in the world at that time, advancing groundbreaking research opportunities regarding magnetic structures and rare earth properties. The ORR offered a neutron flux 300 times that of the Graphite Reactor. As Ralph Moon described, who joined the Neutron Scattering Program group in 1963 just before it was officially absorbed by the Solid State Division, the neutron flux "is measured in neutrons per square centimeter per second. That number tells you how many neutrons are flowing into your experiment… What happened is that the complexity of the experiments followed that increase in flux. When you get more flux, you usually don't just do experiments faster. You do experiments that you couldn't do before because you didn't have enough neutrons" (Wilkinson et al. 2003:8).

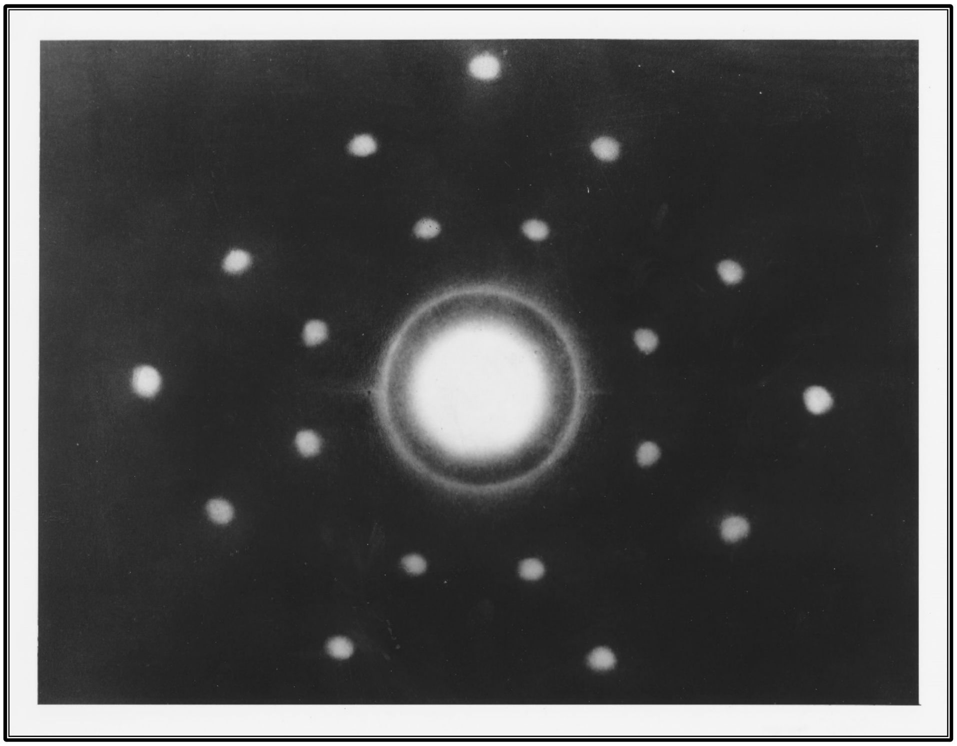

Figure 203. Archival photograph showing the first neutron Laue diffraction pattern ever recorded, made possibly by studies conducted by Ernest Wollan, Clifford Shull, and Milton Marney, circa 1948 (Rumsey 2018).

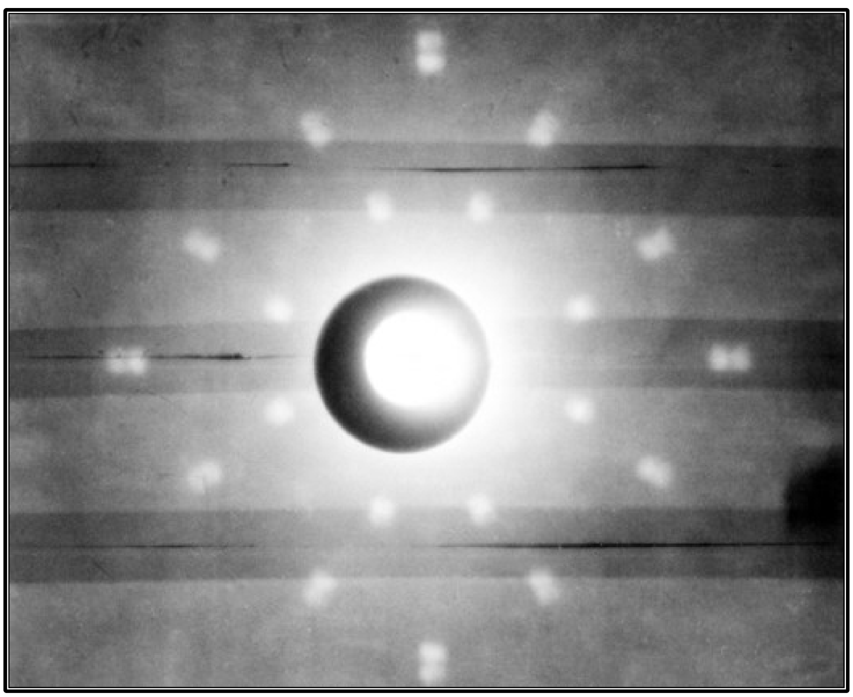

Figure 204. Archival photograph showing the first neutron radiographic image, made up of several indium strips joined by Scotch tape, circa 1948 (Rumsey 2018).

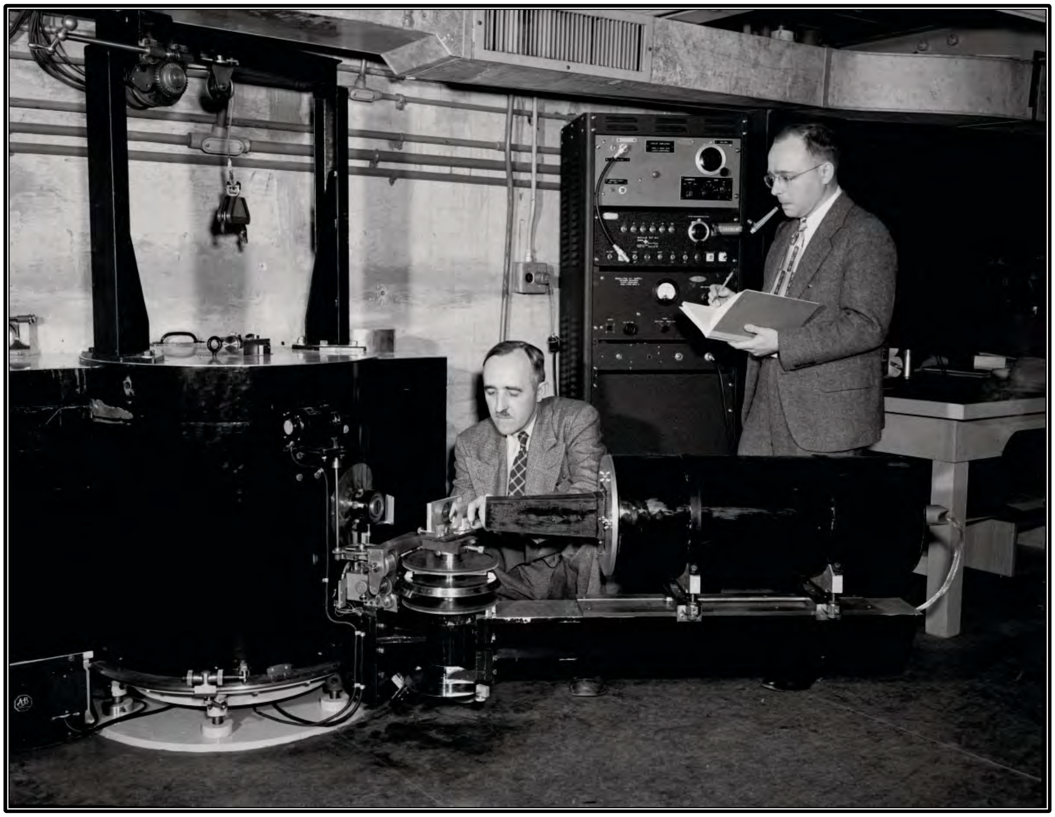

Figure 205. Archival photograph showing Ernest Wollan (seated) and Clifford Shull (standing) working with the world's first two-axis neutron diffractometer, shortly after installation at the Graphite Reactor, circa 1950. This equipment was utilized during the infancy of the Neutron Scattering Program (ORNL News Photo 4357).

The Neutron Scattering Program team at the ORR originally focused on crystallography and magnetism as they had previously at the Graphite Reactor. In 1962, an inelastic neutron scattering group in the Solid State Division, formed by Wilkinson and Harold Smith, originated experimentation to determine dynamic atomic properties in solids and interatomic forces in crystals using inelastic scattering. Inspired by instrumentation in use by Bertram Brockhouse at the Canadian Chalk River Laboratories in Ontario, home to the highest neutron flux in the world before the ORR came online, the Solid State Division built a triple-axis spectrometer at a beam port in the ORR to aid in this research (Figures 206 and 207) (Wollan 1958:55; Johnson and Schaffer 1992f:230–231; Rumsey 2018). As Moon explains, "at the Graphite Reactor, elastic coherent scattering was the main technique used because the researchers could measure the number of neutrons scattered through a particular angle. Beginning at the ORR, another type of experiment involving inelastic scattering, in which both the number of neutrons scattered through a particular angle and their change in energy could be measured. So, neutron cross sections were measured as a function of energy and momentum" (Wilkinson et al. 2003:8–9).

Other Physics Division scientists worked with Harvard researcher Norman Ramsey at the ORR for several years through the 1960s, constructing and operating a novel neutron spectrometer to use in experiments regarding neutron electrical charges. Ramsey would earn a Nobel Prize in physics for this and other proton and neutron studies in 1989. Within the Chemistry Division, crystallography studies involving single-crystal neutron-diffraction research originated at the ORR, unveiling the atomic structures and interatomic forces of various materials, including sugar and other crystals (Johnson and Schaffer 1992d:104, 1992f:230-231; Krause 2003:8; Jones 2018b:50; Cabage 2000:4).

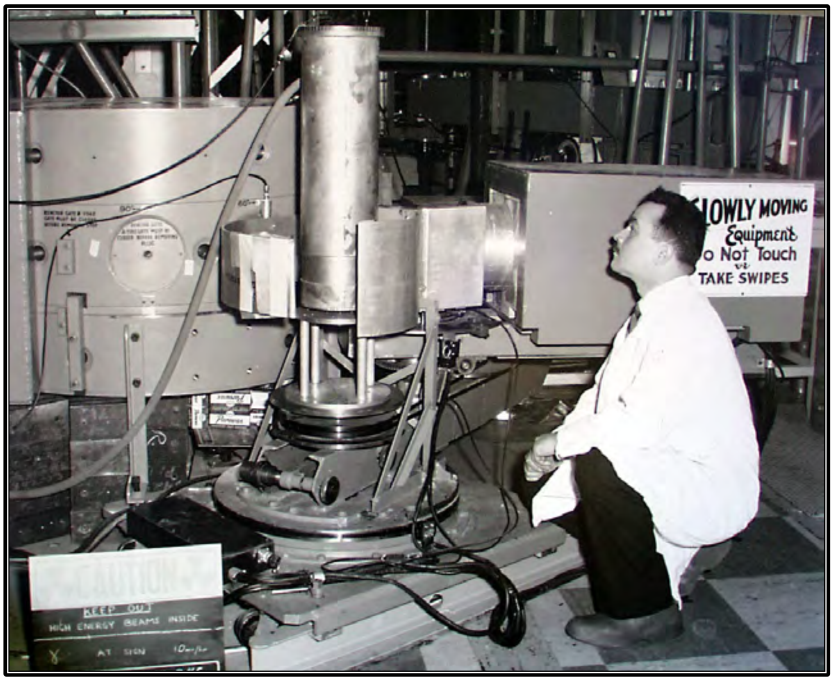

Figure 206. Archival photograph, circa 1957–1961, showing Bertram Brockhouse with his triple-axis spectrometer at Chalk River Laboratories. Brockhouse studied the internal structure of metals using a high energy neutron beam emanating from a nuclear reactor. This triple-axis spectrometer turned while rotating the sample, allowing the beam to hit the sample at changing angles, which generated a three-dimensional view and a molecular-level image using early computer technology. Brockhouse shared the Nobel Prize in Physics with Clifford Shull in 1994 (Photo courtesy of Atomic Energy of Canada Limited).

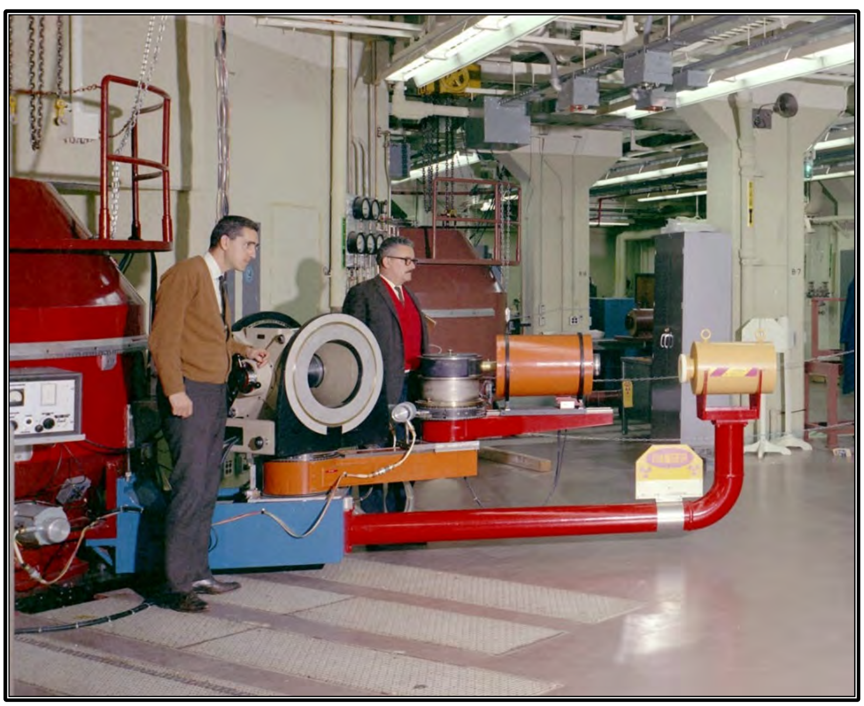

Figure 207. Archival photograph showing an example of a triple-axis spectrometer at ORNL, circa 1969. Ralph Moon (left) and Wallace Koehler (right), both members of the neutron diffraction group, are seen with the first polarized-neutron triple-axis spectrometer installed at the HFIR (Rumsey 2018).

Scientists began discussing their desire for an "Ultra High Flux Research Reactor" by 1957, before the ORR even went critical. During informal seminars ORNL hosted between December 1957 and April 1958, Weinberg, Wollan, Snell, and other scientists determined the most pressing motivation for a higher-flux reactor than the ORR was grounded in isotope production, not neutron science (Lane 1958:3–9). Henri Levy, part of the neutron diffraction team, argued a higher-flux would allow for faster, better, and easier data, and that the factor increase in flux should directly correlate with time saved (Levy 1958:38). Wollan, presenting after Levy, insisted a higher flux necessitated more staff to make efficient use of the equipment, but that the neutron diffraction field had proved to be very attractive for up-and-coming scientists (Wollan 1958:59–60). By April 25, 1958, just one month after the ORR went critical, all of the beam-holes at both the LITR and the ORR had already been claimed by researchers, indicating that the demand for additional research facilities had outgrown even those then newly available at the ORR between 1950, when Snell and Weinberg originally requested what they referred to as the RIR to fulfill the growing demand, and 1958, when construction was completed. Ultimately, however, during that same seminar, Weinberg agreed with Snell that ORNL "would be in a poor way to seek a new reactor even before we have done much with the ORR" (Weinberg 1958:143–144).

Throughout those initial discussions, they referred to the potential reactor as the "High Flux Research Reactor" (Lane 1958:84). When completed in 1965, this ultra-high-flux reactor would be named the "High Flux Isotope Reactor," signifying that their initial assessment that a higher-flux reactor at ORNL would best serve the isotope program proved in the long run to be the best justification for securing the funds for construction (see Figure 179). Nonetheless, Weinberg ensured the inclusion of four ports in the HFIR design to access the reactor's core for advanced beamline instruments to accommodate neutron scattering experiments. Beginning in 1967, the Neutron Scattering Program took advantage of these much higher intensities for use in new types of experiments, where the team could measure not only the scattering angle and energy change, but also the neutron spin within a beam (Rumsey 2018; Krause 2003:8; Wilkinson et al. 2003:9). "Dense streams of neutrons from HFIR illuminated not only crystal structures but also the excited states of atoms, and the high-flux facility's triple-axis spectrometers supported research, first in low-temperature superconductivity and magnetism, then in high-temperature superconductivity" (Jones 2018b:50).

Even after the completion of the HFIR, the Neutron Scattering Program, now under the Solid State Division, continued to utilize the triple-axis spectrometer at the ORR as well as expand upon the equipment options. In 1967, ORNL added a neutron time-of-flight instrument characterized by a magnetic chopper to the ORR as well as a semiautomatic anelasticty apparatus and a continuous-flow helium cryostat to the irradiation beam-hole facilities at the ORR. The new beam-hole devices aided studies regarding low-temperature irradiation effects on copper (Billington and Wilkinson 1968:xiii, 2–8, 42).

Beginning the following decade, with the nation gripped by panic over gas shortages, utilizing the resources at both the ORR and HFIR, the Neutron Scattering Program team sought to "obtain fundamental microscopic information on condensed matter" to contribute to solid state science generally while also working to resolve the long-term energy-related materials difficulties in the United States specifically (Wilkinson and Young 1977:116; Wilkinson et al. 1983:168). At that time, ORNL again added more equipment at the ORR, including a triple-axis crystal spectrometer at HB-1, a polarized beam diffractometer at HB-2, and a small-angle neutron scattering (SANS) instrument at HB-6. The latter allowed for numerous simultaneous SANS experiments, and acted as a mockup for a larger unit to be installed later at the HFIR, discussed below (Figure 208). Early experiments utilizing the SANS instrument primarily contributed to material studies (Wilkinson and Young 1977:116; Child and Spooner 1977a:118–119; Child and Spooner 1977b:121–122).

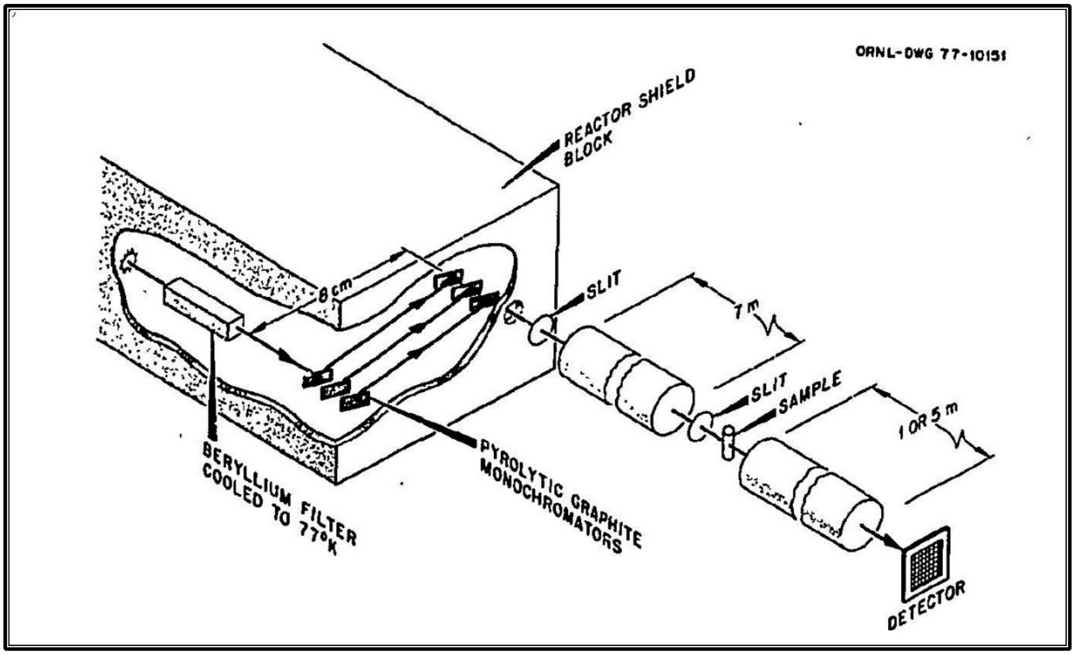

Figure 208. Schematic diagram (ORNL-DWG 77-10151) showing the SANS instrument developed and installed at HB-6 in the ORR, circa 1977 (Child and Spooner 1977a:118).

Between the late 1970s to early 1980s, ORNL commenced numerous collaborative efforts with outside entities. The National Center for Small-Angle Scattering Research (NCSASR) was established on January 1, 1978 as a joint effort between ORNL, the National Science Foundation (NSF), and the DOE. Conceived by members of the NSF in 1976, the mission of the NCSASR was to deliver to scientists across the nation a National User-Oriented Facility for SANS experiments. This goal was actualized in the National Facility for Small-Angle Neutron Scattering, a 30-m SANS instrument located at the HFIR funded by the NSF for full-time use, in 1980. ORNL later expanded the scope of the NCSASR to include part-time access to the high-resolution double-crystal SANS device at the HFIR as well as the 10-m small-angle x-ray scattering camera and the 10-m SANS instrument at the ORR, mentioned above (see Figure 208). All beam time, staff hours, facilities, and equipment under the umbrella of the NCSASR were provided to visiting scientists free of charge. While the primary use of these NCSASR facilities resided in polymer research, other research proposals ranged from physical chemistry to metallurgy to biology. The NCSASR became more formalized in January 1982 and accommodated almost 100 user experiments annually by 1983.

The HFIR was nonoperational between October 1983 and January 1984 for a beryllium reflector replacement. During that time, ORNL reactivated and updated the SANS equipment at the ORR to temporarily accommodate the influx of NCSASR outside users. They planned to maintain operation of this equipment beyond the temporary closure of the HFIR in order to fulfill the anticipated growing demand. Also during this period, the HFIR National Facility for Small-Angle Neutron Scattering was improved upon before reopening to the NCSASR community in June 1984 (Wilkinson et al. 1983:168; Child et al. 1983:170; Koehler et al. 1985:1-3; Solid State Division 1987:1-2).

When the Ames Laboratory Research Reactor in Iowa was shut down in the early 1980s, their neutron scattering program and some of their instrumentation relocated to ORNL. This equipment was installed at the ORR and all neutron scattering equipment, at both the ORR and HFIR, became available to researchers from ORNL as well as Ames. ORNL also collaborated internationally with the Japanese Science and Technology Agency and the Monbusho of Japan in the 1980s under the U.S.-Japan Non-Energy Research Agreement, negotiated by the DOE and finalized on May 2, 1979, having determined that the task of testing candidate fusion reactor materials was too overwhelming for one nation to tackle alone. Through the United States-Japan Cooperative Program in Neutron Scattering, ORNL staff worked with Japanese scientists and the Japanese government funded the addition of neutron scattering equipment at the HFIR and ORR. The work under this collaborative Program initiated in November 1983, with the objective to investigate the irradiation response of structural alloys fabricated in both Japan and the United States to determine their potential functionality in future fusion reactors. Equipment shared under this program included two spectral-tailoring capsules for irradiation experiments at the ORR, installed in 1986. ORNL decided to relocate the investigations involving the ORR to the HFIR later that year in anticipation the ORR would be shut down before the end of the decade (Wilkinson et al. 1983:xx, 168; Scott et al. 1985:1–4; Scott et al. 1986:19–25, 54; Rowcliffe et al. 1988:2, 24–25).

Starting in the mid- to late 1980s, the United States began to fall behind other nations in neutron science technology, a matter that became alarming economically (Cabage 2018:13). Therefore, the DOE realized a growing need for additional major science facilities in the country leading to both upgrades at the HFIR and the construction of the Spallation Neutron Source (SNS), a facility completed in 2006 explicitly constructed for neutron scattering work (Figure 209). Referred to as a "third-generation facility," the SNS was the brainchild of ORNL, ANL, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, and the Thomas Jefferson National Accelerator Facility (Rumsey 2018; Jones 2018b:50). As of 2018, the SNS, listed in the Guinness Book of World Records, was "the most powerful pulsed accelerator-based neutron scattering facility in the world… There, neutrons are generated by propelling protons down an accelerator at nearly 90% of the speed of light until they smash into a liquid mercury target. When the protons collide with the mercury atoms, neutrons are released and sent through vacuum tubes to the facility's 19 surrounding instruments for research" (Rumsey 2018).

Much like the conception of the HFIR while the ORR neared completion, the recognition of a need for a second target station developed while the SNS was under construction. Luckily, due to ORNL's previous experience with boundless growth and the enduring aspiration to keep the United States a world leader in neutron research, the design of the SNS considered the potential for future upgrades. Today, the HFIR and SNS offer a total of over 30 specialized beamlines hosting over 1,000 scientists annually amounting to a highly-competitive proposal process (Rumsey 2018).

Wollan, credited as the pioneer of this crucial field, served as the Associate Director of the Physics Division until he retired in 1967. He continued to provide consultation services for ORNL until 1977 (DOE Office of Science 2016). Shull shared the Nobel Prize in Physics with Brockhouse in 1994 "for pioneering contributions to the development of neutron scattering techniques for studies of condense matter" (Figure 210) (Williams 2018:61). Unfortunately, Wollan passed away in 1984 and therefore could not share in this honor with Shull. Their innovative efforts had since spread to reactors around the world. Jack Carpenter, Senior Physicist Emeritus at ANL, stated in 2016: "This business of neutron beam studies of materials has grown from, say, a few curious scientists to a community that's probably numbered now in the tens of thousands of workers in installations at many places around the world" (DOE Office of Science 2016).

The ORNL Neutron Scattering Program influenced nearly every sector of physical science. By 2003, this research had helped develop high-strength plastics as well as magnetic materials, such as those used in small motors, credit cards, computers, and compact discs; by 2016 it had contributed to the improvement of household paint, photovoltaic cells, biofuels, medical imaging, information storage, and even dish soap. The work pioneered by Wollan and Shull, and supported by the facilities at the ORR, continues to facilitate modern advancement, with the development of better medicine, greener fuels, more durable construction materials, lightweight vehicles, and innovative electronic devices. Neutron science also plays a pivotal role in chemistry and biology (Krause 2003:8; DOE Office of Science 2016; Rumsey 2018).

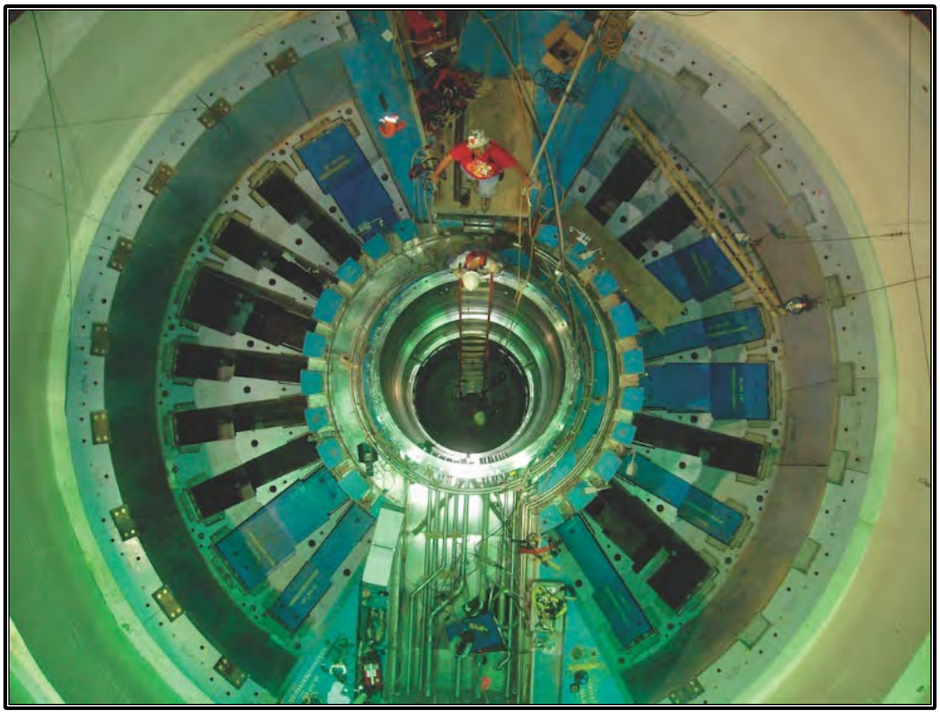

Figure 209. Circa 2006 photograph inside the SNS, a DOE user facility completed in 2006. The SNS was listed in the Guinness Book of World Records as "the world's most powerful pulsed neutron source" (Rumsey 2018).

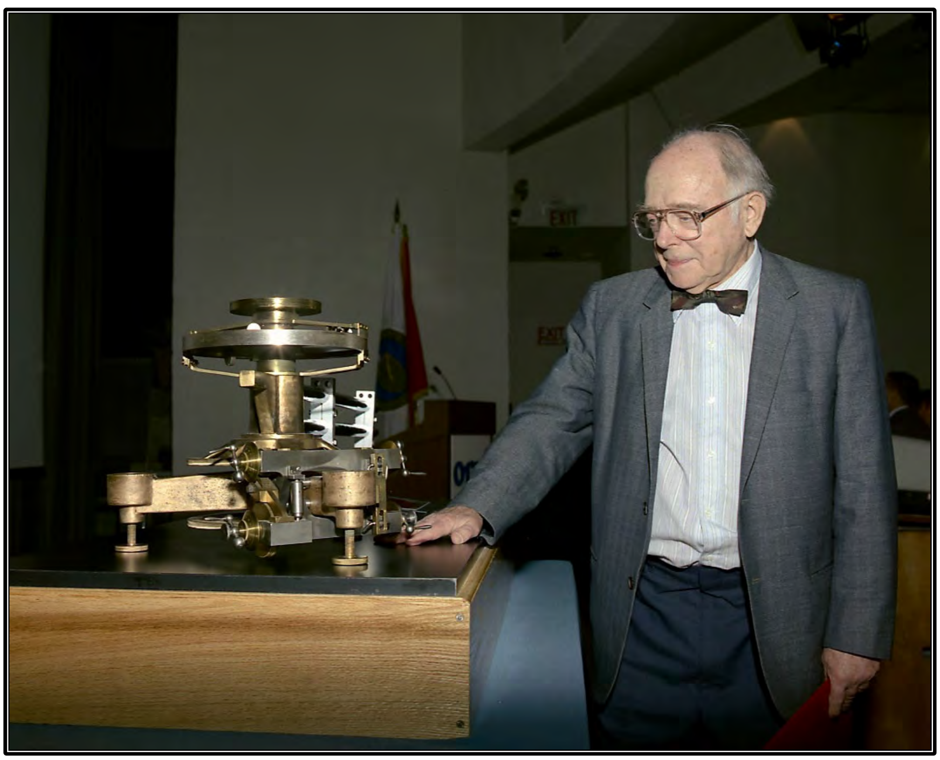

Figure 210. Archival photograph of Clifford Shull at the American Museum of Science and Energy, circa 1990s. Shull won half of the Nobel Prize in Physics in 1994 for his and Ernest Wollan's pioneering neutron scattering research in the 1940s and 1950s. Wollan passed away in 1984 (Rumsey 2018).

The ANP Project

During the post-war time frame, the AEC and ORNL were involved in nuclear propulsion projects with both the U.S. Navy as well as the U.S. Air Force. The U.S. Air Force gave the contract for the Nuclear Energy for Propulsion of Aircraft (NEPA) Project to the Fairchild Engine and Airplane Corporation in 1946. This project was intended to investigate the possibility of using nuclear energy for the propulsion of aircraft while also educating the aircraft engine industry on nuclear science (Figure 211). A conference involving personnel from the AEC Division of Reactor Development, ORNL, the Air Force, and the NEPA Project took place at Oak Ridge on April 27, 1949 to determine how ORNL could be involved. Using ORNL facilities, NEPA and ORNL collaborated on shielding and radiation damage research. The AEC officially established an ANP Program at ORNL in September 1949. Soon afterwards, General Electric replaced Fairchild as the Air Force's contractor and relocated operations to their plant in Ohio, near the Wright Patterson Air Force Base. Over the summer of 1950, numerous scientists gathered at ORNL to discuss potential aircraft reactor designs and ultimately recommended constructing an aircraft reactor at ORNL. In the early 1950s, utilizing data gathered from work with the BSR, these scientists felt optimistic they could reduce the shielding weight, the largest hurdle to overcome in the consideration of an aircraft reactor. This optimism lead led to the construction and operation of ARE between 1953 and 1954, believed by some to be the most advanced reactor type developed at ORNL (Thompson 1963:89–95; Johnson and Schaffer 1992c:66–67). Building 7503 was constructed south of the primary ORNL site to house the ARE (Thomason and Associates 2004:38).

ORNL constructed the ORR to provide flexible experimental facilities for multiple divisions, including the ANP. During the design stages of the ORR, many ORNL divisions were given the opportunity to review and provide input regarding the multiple available irradiation facilities. After the HRE and Chemical Technology Division assisted in the design of the North Experimental Facility, the ANP Division reviewed their proposal in consideration for the South Facility plan. These reviews bolstered the case for increasing the ORR's initial power level to 20 Mw (Gill and Cole 1956:7-9; Cole and Gill 1957:3-4).

The ANP Project, largely focused on not only the successful achievement of the Project mission, but on the inherent safety concerns of an airborne reactor, often involved testing potential reactor materials under various temperatures, levels of radiation (as emitted by a reactor), and pressure (as found in an aircraft). Creep rate experiments considered material integrity given changes in irradiation and temperature, while tube-burst experiments considered the impacts of radiation and pressure. Initially, the MTR was the only reactor available for experiments to "test materials compatibility under irradiation" (Trauger 2003:9). After completion of the ORR, in 1958 the ANP Division built equipment to conduct these types of experiments at the ORR, both in the reactor fuel element lattice as well as in the poolside facilities. These tests also contributed to the growing data regarding ORR capabilities. In 1959, it was discovered that the fast-neutron-fluxes in the pool of the ORR were comparable to those of a beam-hole facility at the MTR and that the geometry was likely improved (Wilson et al. 1959:73; ORNL 1959a:60–62). Additionally, it was found that "[t]he great advantage of the ORR is that there is much more room for specimens, access is easier, and the cost and time required for building experiments is a fraction of that for the MTR" (ORNL 1959a:62). Later that year and into the following, these experiments were continued primarily at the ORR, utilizing the poolside facility. By 1961, the first in-pile tube-burst test apparatus was in use at the ORR (Figure 212). Upgraded equipment, such as this apparatus and the peripheral connected systems, allowed experimenters to eliminate all organic materials, air, and other undesirable variables, in order to achieve a more representative environment and therefore better data (ORNL 1959b:79–83; Staff 1960a:xiv, 73; Staff 1961a:xiv–xv, 77).

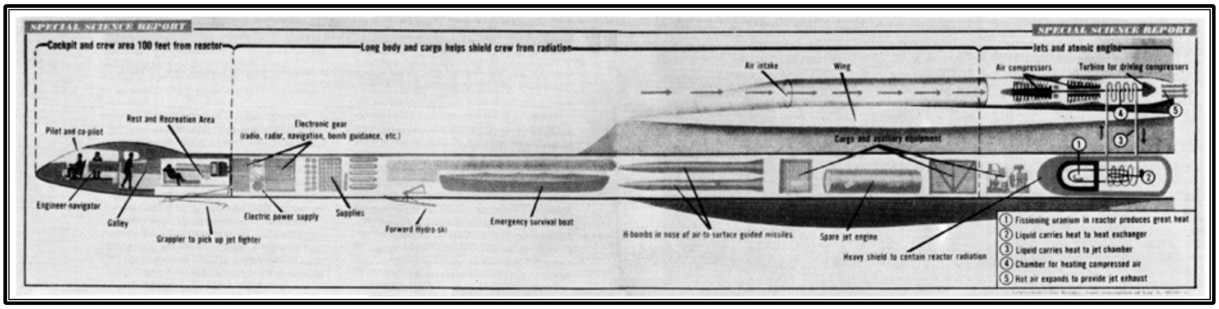

Figure 211. Diagram published in *Newsweek* in the 1950s showing one of the proposed layouts of a nuclear powered aircraft (ORNL Photo 2008-P02983).

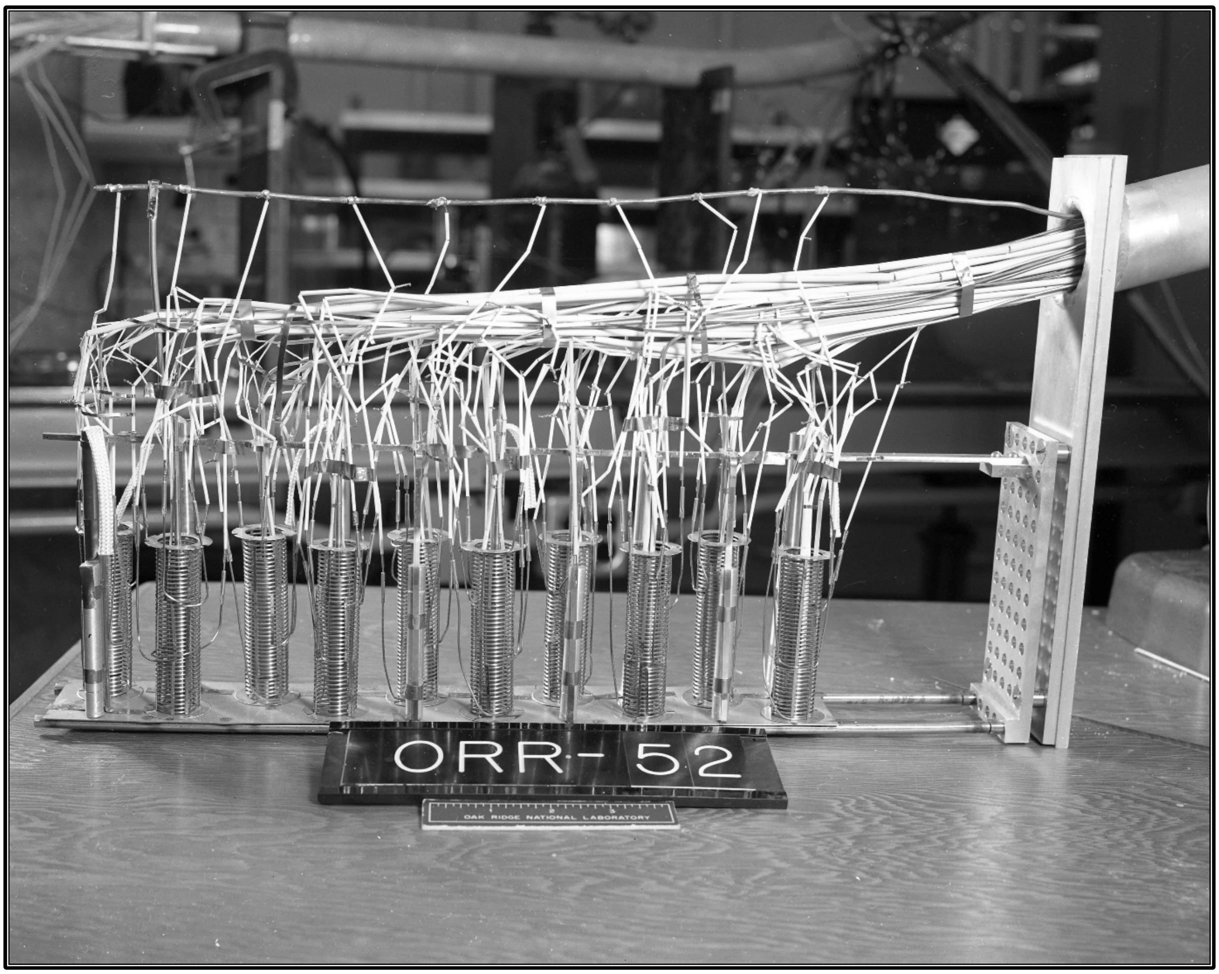

Figure 212. Archival photograph showing an example of a tube burst experiment at the ORR, circa 1962, after the official elimination of the ANP Program by President Kennedy in 1961 (ORNL Photo 58250).

By the time ORNL utilized the ORR for the ANP Project, the program was winding down. In 1958, the same year the ORR became operational, Congress became critical of the high cost and continued relevance of the ANP Program. President Eisenhower ordered a review of the program considering current military needs and ultimately cancelled major components of the ANP program. At ORNL, plans for further development regarding the ANP Project were put on hold. On June 30, 1961, President Kennedy eliminated the national ANP Program entirely (Thompson 1963:96–97).

Many scientists were skeptical of this project, including Weinberg who said "nuclear-powered aircraft is really as good an oxymoron as I've ever heard of, because – in order to have a manned airplane – you had to pile on an awful lot of shielding. And, heavy shielding [makes it difficult for an airplane to get off the ground and stay in the air]. At that time, we were so hungry to do reactor work – and this was an ultimate reactor – that we gladly pitched in and did what we could. Now, the nuclear airplane was canceled by John F. Kennedy – after a billion dollars was spent – and those were the days when a billion dollars was real money" (Weinberg 2003:8). Murray Rosenthal, who came to ORNL in 1953 to work with reactors, was assigned to the ANP Project until he "attended a meeting where an Air Force Colonel told us about how they were going to use the airplanes. After hearing him, I asked my boss if I could get off that program, it was never going to go anywhere" (Rosenthal 2012:16).

While the ANP Project may have earned its skeptics, the benefits of the program to ORNL were noteworthy. Weinberg continued the statement above saying "But, as I think back on it, the reputation of the Oak Ridge National Laboratory in high-temperature materials really stemmed from and grew out of the interest in the nuclear airplane" (Weinberg 2003:8). William Manly, who came to ORNL in 1949 to work in the Metallurgy Division, which eventually became the Metals and Ceramics Division, further stressed the conviction that the ANP Project enriched high-temperature material studies at ORNL, including those conducted at the ORR as discussed above, in a 2003 interview, stating "as far as I'm concerned the Aircraft Nuclear Propulsion Program built the Metallurgy Division" (Manly 2003:6). Furthermore, Manly believed that "another result of the ANP Program was the creation of the reactor engineering group. Those engineers learned how to pump fused salts and liquid metals, how to build big thermos-convection loops and big pump loops, and how to make the valves work. So, that's why the metallurgy and reactor engineers here got a heck of a break out of the Aircraft Nuclear Propulsion Program" (Manly 2003:7). Rosenthal also reflected that "the work done on [the ANP Project] here helped build the Lab because it created a lot of technical capability" (Rosenthal 2012:16).

Maritime Reactor Project

While the ANP Project faltered, ORNL continued alternate nuclear transportation program research, including for maritime propulsion. According to Weinberg, water-moderated reactors such as the MTR, LITR, and BSR also "anticipated the nuclear navy. In fact, the [reactor type in the submarines of the] nuclear navy is basically a pressurized version of the MTR" (Weinberg 2003:7–8). Two of the early reactor work developers at ORNL, Paul Haubenreich and Sam Beall, agreed that "[t]he LITR was the direct ancestor of the water-cooled reactors used in Navy submarines" and "[t]he submarine reactors had different fuel elements but they were water-cooled and had enriched uranium fuel and a lot of the technology in the MTR and LITR went into the design of the Navy's reactors" (Beall and Haubenreich 2003:5). The *USS Nautilus* was the first successful nuclear submarine, setting sail and "underway on nuclear power" in 1954 (Figures 213 and 214). As of 2015, nearly half of the Navy's combat vessels were nuclear powered, including 10 aircraft carriers, 55 attack submarines, and 18 strategic submarines. Nuclear propulsion plants have safely powered over 157 million miles of travel for these vessels. More than 150 ports welcome nuclear maritime vessels, scattered across over 50 countries (DOE and Department of the Navy 2015:1).

Figure 213. Archival photograph of the *USS Nautilus* launching ceremony on January 21, 1954 (DOE and Department of the Navy 2015:iv).

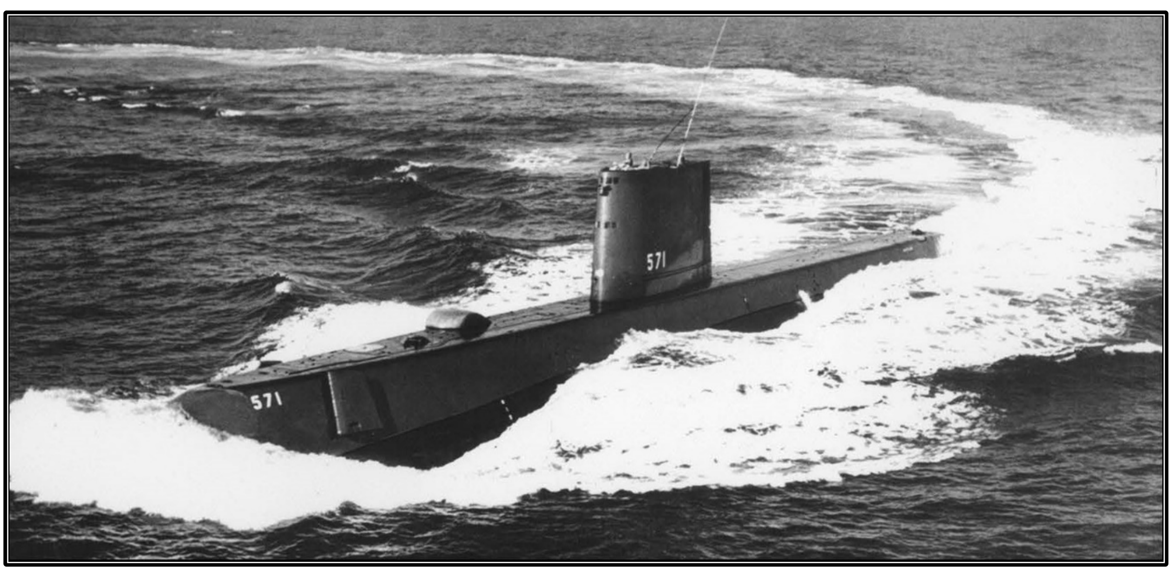

Figure 214. Archival photograph of the *USS Nautilus* (SSN 571) at sea, undated (DOE and Department of the Navy 2015).

In September of 1957, just a few years after the *USS Nautilus* set sail, ORNL, via the Package Reactor Group of the Reactor Projects Division, started the Maritime Reactor Project (later referred to as the Maritime Reactor Program), intended to provide technical support to a program seeking to develop nuclear-powered merchant ships. Much of this research occurred at the ORR. The Maritime Reactors Branch of the AEC Division of Reactor Development and the Nuclear Power Office of the Maritime Administration of the U.S. Department of Commerce cooperatively administrated this program and ORNL provided design and specifications review, technical advice, and experimental and research programs. The primary focus of ORNL's involvement pertained to the *N.S. Savannah* project (Boch 1959:iii, 1; 1960:1).

The *N.S. Savannah*, the world's first nuclear-powered merchant ship, was named for the *S.S. Savannah*, the first steamship to complete a transatlantic voyage partially using steam power. President Eisenhower proposed building a nuclear-powered merchant ship in 1955 as part of his Atoms for Peace initiative. The construction of the nuclear-powered *Savannah* by the Maritime Administration in partnership with the AEC was authorized in July 1956 and the contract with the New York Shipbuilding Corporation for its construction was signed in December 1957. The *N.S. Savannah's* keel was laid on May 22, 1958 in celebration of National Maritime Day, a holiday designated in 1933 to commemorate the beginning of the *S.S. Savannah's* voyage on that date in 1819 (Maritime Administration 1970a:1). The *N.S. Savannah* assumed two goals: "to show the world this country's determination to develop the peaceful, productive uses of atomic energy, and to demonstrate the feasibility of using this energy to propel merchant ships" (Maritime Administration 1970b:1).

The Nuclear Merchant Ship Reactor (NMSR) and the propulsion equipment that powered the *N.S. Savannah*, both furnished by Babcock & Wilcox Co. of Lynchburg, Virginia, were comprised of "a pressurized-water reactor fueled with slightly enriched UO2 [uranium dioxide] pellets canned in stainless steel tubes. A steam-turbine drive will deliver 20,000 SHP [shaft horsepower] to a single screw which will propel the ship at a normal cruising speed of 21 knots" (Boch 1959:1). Similar to a traditional oil-burning vessel, the NMSR produced heat through fissioning to create the steam necessary to turn the turbines. "In the type of reactor installed in the *Savannah*, water is circulated under pressure through the heart, or core, of the reactor as the fissioning process takes place. The water removes the heat created in the reactor core and transfers this heat to water in a secondary system of piping by means of a 'heat exchanger'… Water in this secondary system is changed to steam for propulsion of the vessel" (Maritime Administration 1970b:5). The promoted advantage of nuclear-powered maritime vessels focused on the operation time a single load of fuel would supply, as well as the promise of higher sustained speeds and the projected lower cost of nuclear fuel as compared to fossil fuel. Additionally, reactors demanded less space than fuel tanks and traditional equipment, allowing more room for cargo (Maritime Administration 1970b:5).

The Maritime Administration suspected the new technology might not immediately bode confidence. To address safety concerns, the *N.S. Savannah* boasted multiple layers of radiation shielding enclosing the reactor, including a 17-ft tall carbon steel tank coated with a 2- to 4-inch layer of lead. A steel containment shell surrounding the NMSR was encompassed in a cradle of steel, the bottom half of which was further shielded by four feet of concrete. The concrete provided not only radiation shielding, but structural integrity in the event of collision. "Protection of the containment complex from ship accidents was studied in detail in establishing the *Savannah's* design criteria. In particular, ship collisions were carefully reviewed and methods were developed to predict structural damage to vessels struck in collision. On the basis of these studies, the *Savannah* was designed and constructed to withstand, without damage to the nuclear reactor compartment, any collision with any of the ships making up 99 percent of the world's merchant fleet" (Maritime Administration 1970b:7).

Between February 1958 and December 1959, ORNL designed and built a pressurized-water in-pile loop to test fuel elements for the NMSR, including up to six fuel pins, in simulated pressurized-water reactor operating conditions (see Figures 77–80). After considering the MTR and the Engineering Test

Reactor (also known as the ETR), both located at the National Reactor Testing Station in Idaho, the ORR was selected due to spatial availability and an accessible location for continual maintenance and operation requirements. This loop supplemented the pre-existing Babcock & Wilcox Company's test program. Additionally, outside of the reactor pool, ORNL examined test and control specimens, looking for any distortion or damage due to irradiation. The data accumulated from this research would also contribute to the growing body of knowledge regarding water-moderated reactors, water-chemistry in pressurized-water systems, and other basic or applied studies pertaining to a situation involving both radiation and high-temperature water (Boch 1959:iii, 10, 23).

The stainless steel ORR loop circulated water past two test sample sets, one set located in the in-pile section of the loop and a second control set located external to the reactor, each consisting of six fuel pin specimens. The in-pile portion of the loop was located in lattice positions A-1 and A-2. A cubicle in the basement contained recirculation equipment. Overall, the loop consisted of "an in-pile section, a main loop heat exchanger [to remove heat from the water], canned-rotor pumps for circulation, electric heaters for temperature control, a surge tank, a purification system, an out-of-pile test section [for control specimens], a water sample station, a dump tank, and a water makeup system. All process equipment except the in-pile section, sample station, dump tank, and makeup system are located within the shielded equipment cubicle [in the basement]. Instrumentation and controls are provided for the recording and readout of data and for automatic control of equipment. The entire facility is conveniently arranged for a minimum of operating and maintenance requirements" (Dudley et al. 1963:5; Boch 1959:10). Access was provided for inserting and removing test specimens, a bypass purification and sampling system was installed to control water-chemistry, and provisions were made to attach equipment allowing chemistry studies (Dudley et al. 1963:1). This novel testing facility inspired similar facilities to be developed in the Netherlands and other international locations (Johnson and Schaffer 1992d:105).

In addition to materials testing, the ORR loop also contributed to research regarding the NMSR waste disposal practices. Waste disposal investigations centered on the disposal of ion-exchange resins, which comprised the highest concentration of radioactive waste. By producing ion-exchange resins under conditions similar to that expected in the NMSR, ORNL was able to measure the amount of resins expected to be produced and utilize those resins in various experimental disposal methods. Rather than to discharge the resin waste directly into the ocean, researchers determined it best to control the release in fixed amounts. One method involved mixing the ion-exchange resins with ordinary Portland cement in a drum that would be sealed and dropped into the ocean. This theory also required studying systems for remote handling of the radioactive wastes while on board (Boch 1960:11-16). Ultimately, crew collected the low-level radioactive liquid waste at levels under those required by AEC policy. Liquid waste could be disposed of at sea or transferred in port to a licensed waste-disposal contractor, along with the solid radioactive wastes. The ship mast, armed with radiation monitors, vented gaseous wastes into the atmosphere within the established tolerance limits (Maritime Administration 1970b:8).

The Maritime Commission completed the construction of the *N.S. Savannah* in 1959 and the ship was launched on July 21 that year. As the NMSR design became fixed toward the end of 1959, ORNL support activities began to shift toward review of a second reactor core. ORNL also assigned an engineer to assist onsite in the startup testing program at the Shipyard (Boch 1960:1-2). After irradiation tests of non-pelletized uranium dioxide fuel in the ORR loop were conducted, the AEC decided to halt further research on replacement NMSR cores. ORNL had anticipated the Maritime Reactor Program to continue beyond the *N.S. Savannah* and provide additional research for other potential Maritime pressurized-water reactors; however, the ORR loop facility was reassigned to the Army Reactors Program in July 1962, after fuel irradiation tests were completed. The fuel specimens that had already been irradiated were examined through the end of the year (McCurdy 1963:vii, ix, 2; Dudley et al. 1963:1).

The NMSR achieved criticality on December 21, 1961. During the initial sea run in March 1962, the *N.S. Savannah* attained 80% full power (McCurdy 1963:1). The first domestic voyage for the *N.S. Savannah* commenced in August 1962 (Figures 215 and 216). In 1964, true to its namesake, the *N.S. Savannah* would embark upon its own transatlantic crossing. The 21,000-ton merchant ship could sail for 300,000 miles without refueling. The first refueling occurred on August 20, 1968 in Galveston, Texas, when 4 of the 32 fuel elements were replaced and the other 28 were either rotated or relocated. This provided enough nuclear reactivity to continue operation for another two to three years. Between 1962 and 1969, the *N.S. Savannah* "burned approximately 147 pounds of uranium, which is equivalent to 25,900,000 gallons of fuel oil. This would fill 2,590 standard rail tank cars which would make a train approximately 17 miles long" (Maritime Administration 1970a:4). By 1970, the ship had visited 76 ports across 26 countries for a total of 399,170 miles and had hosted 1,389,780 visitors, 848 passengers, and 208,650 tons of cargo (Maritime Administration 1970b:4)

The pioneering *N.S. Savannah*, while never intended to compete economically with traditional oil-fueled vessels, failed to inspire the construction of additional similar vessels and, therefore, was both the first and last U.S. nuclear-powered merchant ship. The new technology failed to rouse trust from the public in time to maintain the drive. This venture would be the final nuclear transportation project ORNL became so intimately involved with, despite the lofty postwar visions of nuclear-powered trains, automobiles, and even space shuttles (Johnson and Schaffer 1992c:95; Maritime Administration 1970b:1)

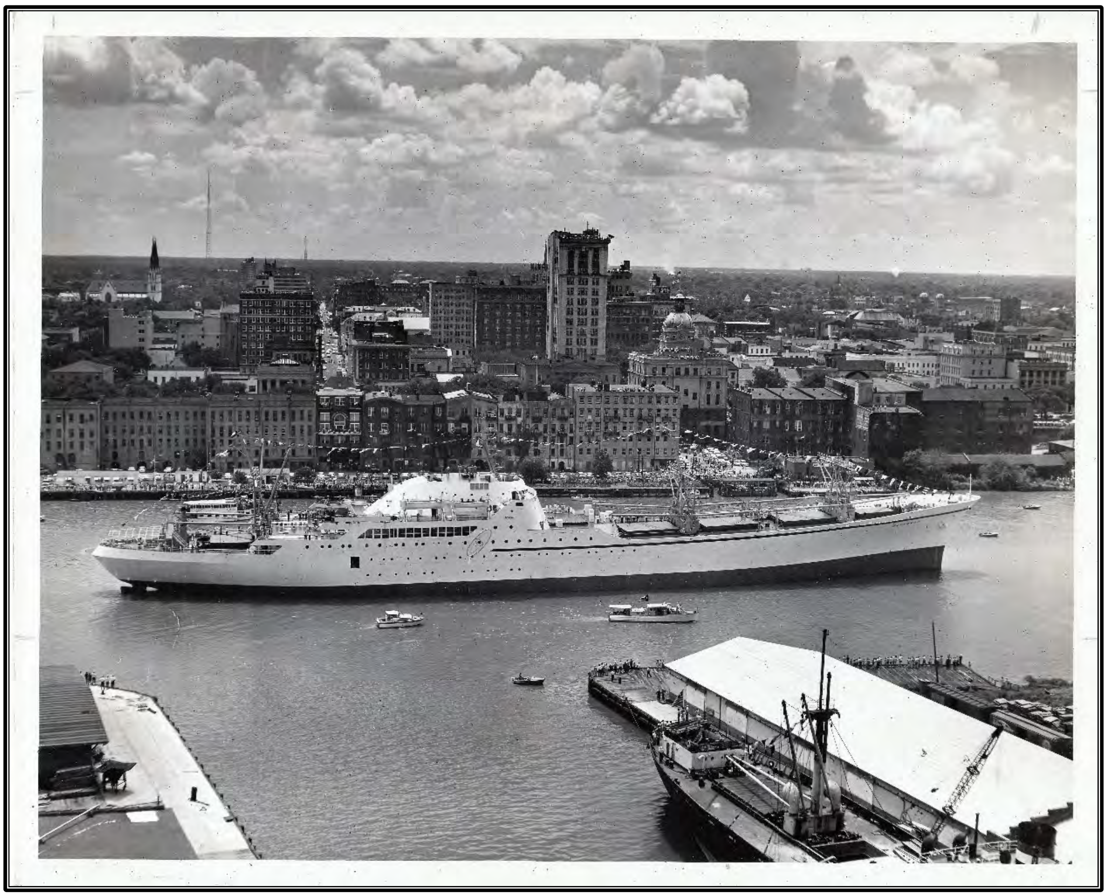

Figure 215. Archival photograph of the *N.S. Savannah* during its first domestic voyage, circa August 1962. The ship is seen here visiting its home port and namesake, Savannah, Georgia (Courtesy of Ships of the Sea Maritime Museum).

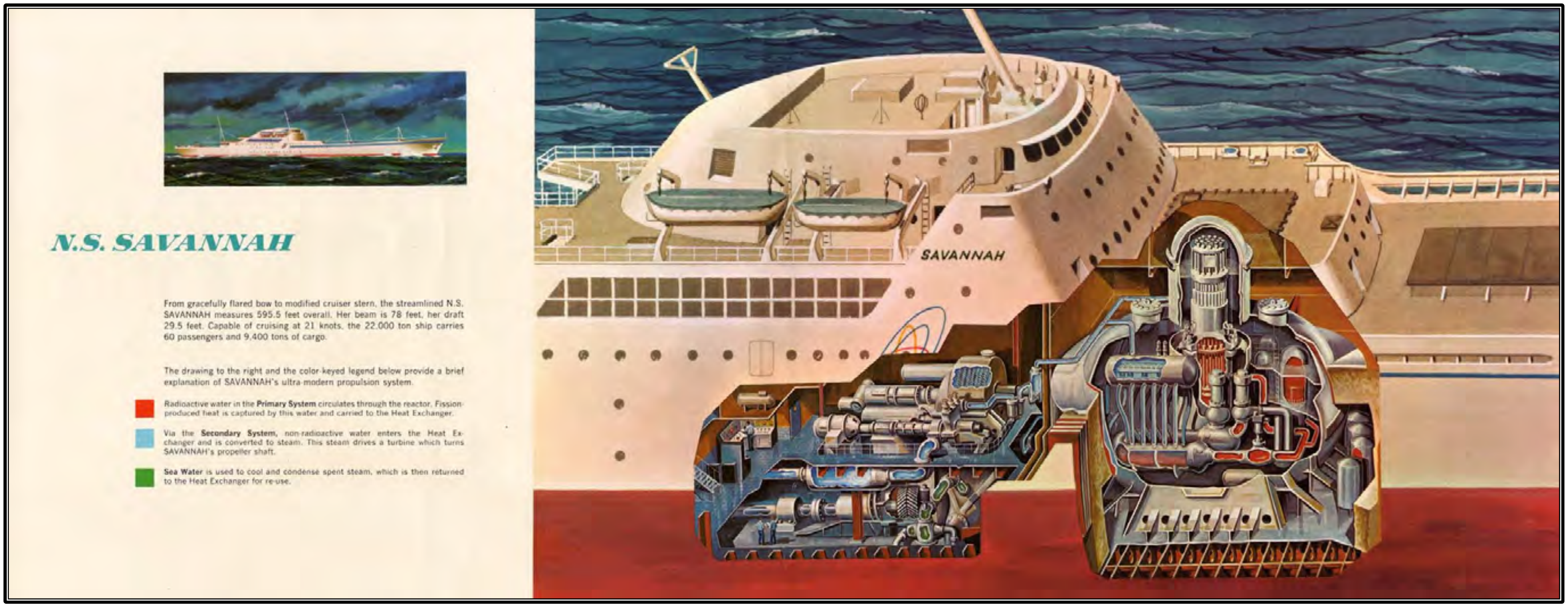

Figure 216. Drawing of the *N.S. Savannah* showing cutaway views of the on-board reactor and nuclear propulsion system, including a color-keyed legend and brief descriptions (American Export Isbrandtsen Lines 1964:5-6; Courtesy of Ships of the Sea Maritime Museum).

Additional Reactor Engineering Experiments

In addition to the ANP and Maritime Reactor Projects, ORNL designed the ORR to contribute to general reactor engineering development research. This included testing candidate structural materials and reactor fuels. The first reactor designed specifically to test the capability of various potential reactor materials to withstand irradiation was the MTR. The ORR, however, constructed with the intention of providing the scientific community with a high-power, flexible reactor in a more convenient location than that of the MTR, also permitted reactor material research. Jim Weir, the Division Director for the Metals and Ceramics Division for several years, recalled:

> *We did a lot of testing of metals and ceramics at the ORR. We had instrumented facilities. In fact, my team put together the first instrumented materials radiation facility in the ORR fuel core. Back then things were done in the "pool side" outside the vessel. We wanted to get some high neutron fluxes, so we got inside the core -- very hard to do. It was a mess. Welding of aluminum is difficult at best, and, if you have to do it in thick sections, it's almost impossible. So, we had to build the first can to be about three feet long so it could contain the fuel elements. The can had to fit down in the same place a fuel element would fit, and it must be pressure sensitive to sufficiently contain the pressure if anything does happen inside. So, making that can, curving the heavy, quarter-inch-thick plates and welding the seams up, was a nightmare. And we had the two best aluminum welders in the Laboratory, who worked twelve hours a day for three days. It took both of them to do the welding. I was there most of the time. We finally got that can made and inserted it in the reactor core on schedule. But after that, we changed our approach and bought extrusions of these cans. They were big long sections that could be chopped up…. A single piece. That's very easy to do with extruded aluminum… So, once we decided we couldn't do it easily by welding, we looked for a simple way, and that was it. So after that time, everyone who wanted to run an experiment inside the core of the reactor used the aluminum can* [Weir 2003:9-10].

One of the most significant reactor engineering programs at the ORR focused on developing a gas-cooled nuclear reactor, known as the EGCR Project. After Congress learned of Britain's gas-cooled power reactors constructed in the 1950s, they directed the AEC to begin preparations to build one in 1956. Similar to the air-cooled, graphite-moderated Graphite Reactor, the British reactors were carbon dioxide-cooled and graphite-moderated. Initially, ORNL leadership tasked a study team to compare the feasibility and expense of GCRs to that of water-cooled reactors. By the end of the decade, the AEC directed ORNL to focus on fabricating the fuel elements and moderator for the EGCR Program (Manly 2003:10; Johnson and Schaffer 1992d:108–109).

Fuels for the EGCR were first tested in the MTR in Idaho, but the ORR provided a more convenient location in the vicinity of the proposed site for EGCR facility construction. Donald Trauger, who worked closely with the ANP Project, irradiated materials at multiple reactors for several experimental designs, including that of the EGCR. "For testing the EGCR fuel, which is a different kind of fuel, we put capsule experiments – nuclear fuel in a solid ceramic – in the Oak Ridge Research Reactor. We needed more capacity because the AEC wanted to move the Gas-Cooled Reactor along rapidly… we put a fuel test loop cooled with helium in the Oak Ridge Research Reactor. So, we really had quite a large irradiation testing program" (Trauger 2003:9). Under the direction of personnel previously associated with the ANP Project, such as Trauger, the EGCR Program utilized similar experimental methods, including tube-burst-type stress-rupture tests (Staff 1960b:174).

ORNL proposed a helium-cooled GCR in 1958 (Johnson and Schaffer 1992d:108). EGCR Project personnel gained access to the ORR poolside facilities for the installation of eight experiments (Trauger 1958:176–179). Between 1959 and 1960, an experimental loop facility, to become GCR-ORR Loop No. 1, was installed at the ORR, designed for fuel material research, focusing on ceramic fuels under high-temperature irradiation (Figure 217, see Figures 81 and 82). "[T]he design consists of concentric in-pile tubes containing a removable test capsule cooled by recirculated gas… This loop, in contrast to other larger loops which are to be used for testing prototype fuel elements, was designed primarily for studying fuel materials at high temperatures" (Staff 1959:120–124). Staff built the loop facility as a "package," removable and replaceable as a single piece, including all components and the test section. While Loop No. 1 was nearing completion, plans progressed for ORR in-pile Loop no. 2, referred to as GCR-ORR Loop No. 2 (Staff 1959:x, 106–112, 120–124, 160; Staff 1960b:xxiii–xxiv, 226).

The GCR-ORR Loop No. 2 was housed in a stainless steel lined containment cell containing a movable rack mounted to tracks to which all the loop components were affixed, a five-ton crane, and a remotely operable manipulator. This air-tight, double-contained facility, completed in the early 1960s, allowed EGCR Project scientists to study numerous aspects of unclad fuel element design, such as those to be used in the proposed EGCR. Loop No. 2 accessed the reactor core via the south side pool beam hole facility (Figures 218–220) (Gnadt et al. 1961:262–265; Dudley et al. 1961:207; Zasler et al. 1962:3–5, 20, 24–25).

"Coated particles," of interest to the EGCR Program, were undergoing irradiation studies at the ORR by mid-1960 (Staff 1960b:166). As Trauger described: "We learned how to coat tiny particles of fuel, about the size of the lead tip of a small, fine lead pencil… They're very small, and they are coated with graphite and silicon carbide to make them impervious. They're really tough little nuts. You put them in a graphite matrix, where they can withstand very high temperatures" (Trauger 2003:10). Given the investment made in unclad fuel element research, including the GCR-ORR Loop No. 2, the advancement of coated particles through the 1960s did not bode well for the overall EGCR Program.

Ultimately the EGCR never ran and the EGCR Program failed. Bill Manly of the Metallurgy Division oversaw the EGCR Project for a few years in the 1960s. He recalled the ending of the Project: "by that time, the politics changed. Other people were taking over reactor projects and private enterprise was looking at them. That was a time when General Atomics came along and [expressed interest in developing gas-cooled reactors]. Also, what changed was the way we handled the fuel for gas-cooled reactors. We started looking at pyrolytic graphite-coated fuel particles in a graphite matrix, which got to be a big thing… [by the time the ORNL gas-cooled reactor was completed] it was outmoded" (Manly 2003:10). The AEC ordered the EGCR Project to be abandoned in 1966, despite the fact that construction of the reactor and its facility had been completed (Figure 221). Water-cooled reactors, such as the ORR, had proven so successful at that point that the EGCR prototype was obsolete before it was started up. By 2013, the British GCRs were either retired or in the process of shutting down, replaced with the water-cooled reactor technology ORNL had become famous for (Barton 2013:32; Johnson and Schaffer 1992d:108–109).

Experimentation at the ORR contributed to numerous reactor designs beyond the EGCR. Inspired by Eisenhower's Atomic Energy Act of 1954, the AEC sought to develop five new reactor designs, including designs revolving around the use of pressurized-water, boiling water, sodium graphite, and aqueous homogeneous-fuel. ORNL was an integral contributor to these reactor designs, specifically the homogeneous reactor. Through the 1950s and 1960s, ORNL frequently had multiple reactor designs in progress (Johnson and Schaffer 1992d:96–97). By definition, "homogeneous reactors rely on the same solution for fuel, moderator, and coolant. This mixed solution circulates continuously, so a homogeneous reactor does not need to be stopped to discard spent fuel. However, because the fuel solution circulates through the entire reactor, not just the core, workers must contend with more radioactive components, which can make maintenance tedious and costly" (Jones 2018a32). Reactor engineering and fuel research at the ORR contributed to homogeneous reactor fuel system technology, such as that used in the experimental designs of the MSRE and the HRE, by way of an in-pile loop simulating a proposed high-pressure system under irradiation (Briggs et al. 1959:164–165; Savage et al. 1960:4). The molten salt test loop, used to analyze homogeneous fuels, operated from approximately 1959 to 1967. The molten salt loop experiment failed in 1966 and necessitated removal from the ORR, which required an unexpected shutdown (Tabor and Hurt 1967:4, 10). The ORR also contributed to the development of fluid fuels for nuclear reactors more generally. These experiments sought to determine not only efficiency of various fuels, but safety. Personnel tested potential reactor fuels by subjecting them to the ORR neutron stream (Johnson and Schaffer 1992d:104–105).

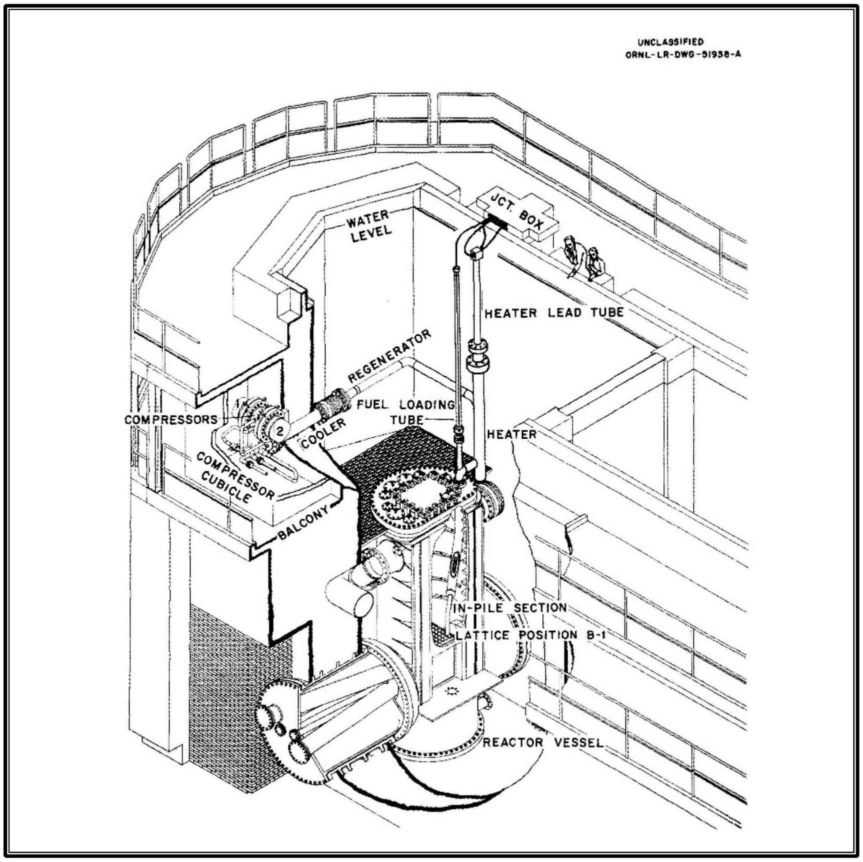

Figure 217. Drawing (ORNL-LR-DWG 51938-A) showing the main components of the GCR-ORR Loop No. 1 as installed in the ORR reactor core, circa 1962 (George 1962:39).

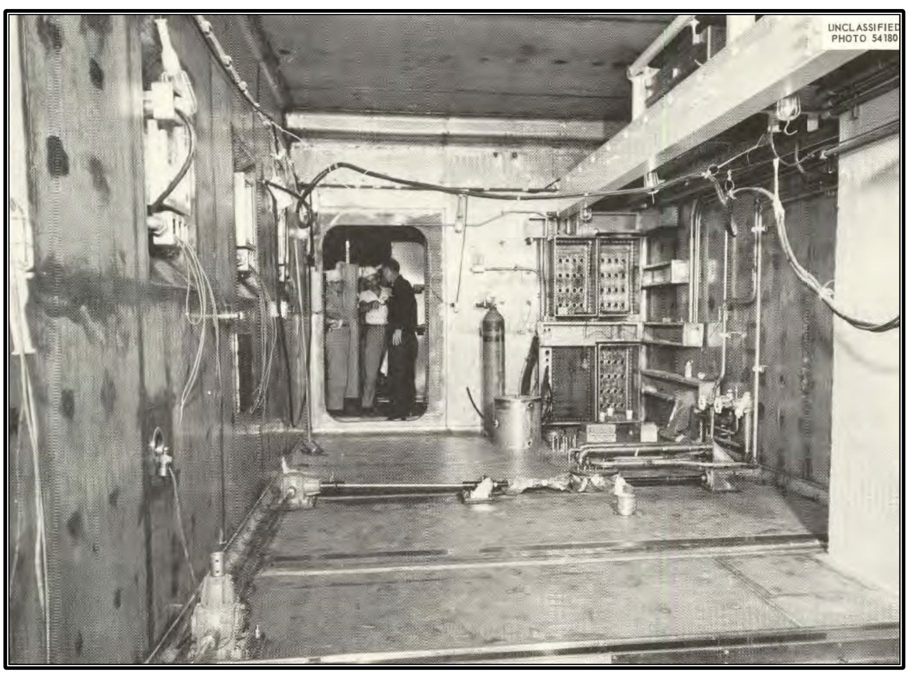

Figure 218. Archival photograph, circa 1961, showing the GCR-ORR Loop No. 2 containment cell prior to the rack and component installation (ORNL Photo 54180) (Dudley et al. 1961:208).

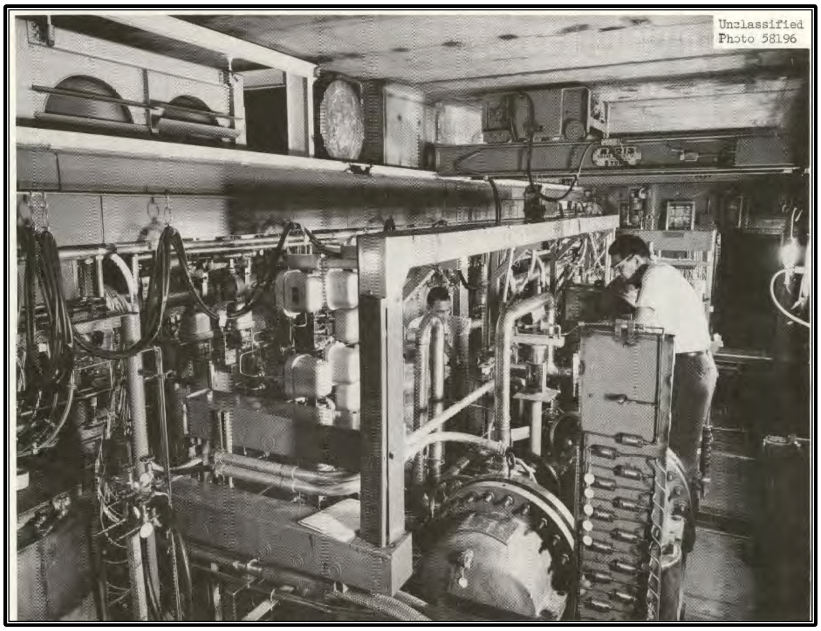

Figure 219. Archival photograph, circa 1964, showing the GCR-ORR Loop No. 2 equipment located inside a containment cell (ORNL Photo 58196) (Trauger 1964:55).

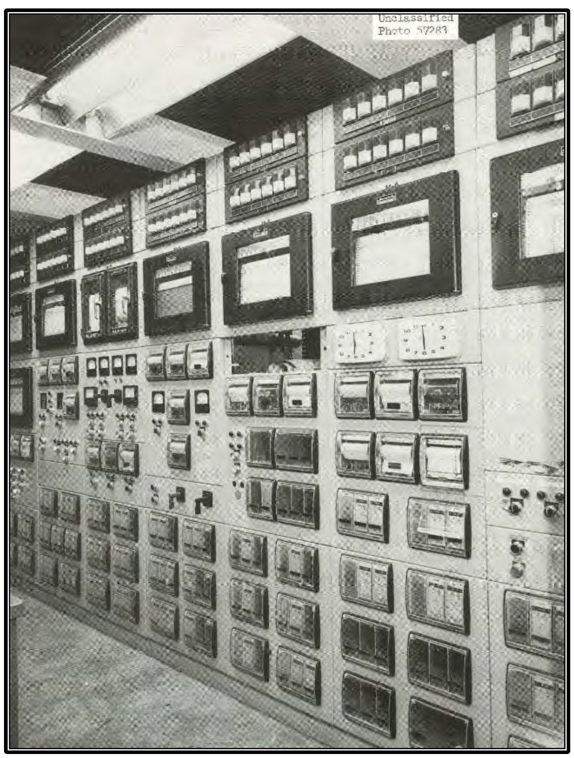

Figure 220. Archival photograph, circa 1964, showing the main instrument control panel for the GCR-ORR Loop No. 2 in the basement of Building 3042 (ORNL Photo 57283) (Trauger 1964:56).

Figure 221. Archival photograph showing the EGCR facility at ORNL, circa 1995 (ORNL Photo 02144-95) (Rosenthal 2010:13).

Reduced Enrichment Research and Test Reactor Program

The ORR also became internationally recognized as an integral component to the Reduced Enrichment Research and Test Reactor (RERTR) Program in the United States during the last decade of its service life. In the mid-1970s, India conducted initial nuclear weapons testing and, in response, Pakistan fast-tracked their own nuclear weapons program (Nunez 2020). Approximately half of the world's research reactors utilized HEU at that time, raising concerns over the potential for nuclear proliferation as this material could theoretically be diverted for weapons use, especially during fabrication, transport, or storage prior to its irradiation (Travelli et al. 1982). President Jimmy Carter officially voiced concerns on behalf of the United States Government in 1977. The DOE implemented the RERTR Program in 1978 with the mission to generate the technical data necessary to support the replacement of HEU in reactors around the world with reduced-enrichment fuel, or LEU, in preparation to curtail the international export of HEU from the United States (Stahl 1982:1).

During the Atoms for Peace Program initiated by President Eisenhower in the early 1950s, the United States contributed LEU to an international stockpile, providing fuel for any low-power research reactors constructed globally (Rosenthal 2010:45; Charpie 1955:33). As Eisenhower stated in his famous December 1953 speech, this fissionable material was "allocated to serve the peaceful pursuits of mankind" (Nunez 2020). The United States exported LEU exclusively until the early 1960s. The Geneva Reactor, discussed above in the "Predecessors to the ORR" section, was also fueled by LEU. As research reactor use expanded in many nations, increased research demands for higher power and neutron fluxes inspired the replacement of LEU with HEU. The growth of active experiments in reactors diminished their fuel lifetime, increasing the costs of operations. While developing fuel with a higher uranium density would have satiated these growing experimental needs, most operators opted for increasing the uranium enrichment as, by the mid to late 1960s, HEU was readily available. HEU thusly became the common fuel for research reactors around the world, even those that could have effectively operated using LEU. Between the mid-1960s and 1977, little research had been conducted regarding potential research and test reactor fuel technology (Stahl 1982:1; Travelli 1983:1-2).

The availability of weapons-grade fissile materials, such as the HEU utilized in these reactors, carried substantial risk for international nuclear proliferation. The International Nuclear Fuel Cycle Evaluation Program (also known as the INFCE), the Nuclear Alternative Systems Assessment Program (also known as the UASAP), and several countries felt compelled to restrict the accessibility of HEU for research and test reactor programs. This recognition instigated an international cooperative effort involving scientists, policymakers, regulators, and industry representatives. The United States announced the Nuclear Non-Proliferation Act Initiative in 1978 as well as plans to develop reduced-enrichment, uranium-based fuels under the RERTR Program. This Program sought to "reverse the trend that prevailed in the 1960's, and to concentrate on renewed fuel development, demonstration and design activities to provide the technical foundation which will allow research and test reactors to achieve their performance/safety/economics goals without reliance on HEU materials" (Travelli 1983:2).

As of 1981, approximately 300 research and test reactors operated worldwide, 156 of which were fueled with HEU exhibiting enrichment between 70 and 94 percent exported by the United States. Approximately 5,000 kilograms of HEU existed around the world at any point in time. Individual reactors utilized anywhere from 1 kilogram of HEU for 20 years of operation to more than 100 kilograms annually, dependent upon factors unique to each system. LEU is defined as nuclear fuel exhibiting uranium enrichment of less than 20 percent but more than that occurring naturally in uranium (Travelli 1980; Travelli et al. 1981; Nunez 2020).

ANL managed the RERTR Program and delegated ORNL as the site for irradiation testing (Senn and Martin 1981:2). Inherent to its mission, research and testing results were made freely available. Multiple countries participated in this international technology transfer, contributing to research relevant to reactor operation utilizing LEU as well as the fuel fabrication. Outside the United States, multiple nations, such as Canada, France, Germany, the United Kingdom, and Argentina, supported programs investigating reduced-enrichment reactor fuel research (Stahl 1982:2; Senn 1989:2–3; Travelli et al. 1981; Travelli et al. 1982). Within the United States, multiple federal agencies collaborated to advance the RERTR Program, including the DOE, the Department of State, the Department of Defense, the Arms Control and Disarmament Agency, and the Nuclear Regulatory Commission (Travelli 1983; Matos 1996:1). The International Atomic Energy Agency (also known as the IAEA) also introduced a fellowship program to train the reactor operators of those reactors undergoing LEU conversion. In 1981, scientists from Austria, Romania, and Turkey traveled to ANL to participate in this training fellowship (Travelli et al. 1981).

In addition to reducing the nuclear proliferation concerns worldwide, the RERTR Program sought to avoid negatively impacting the reactor programs involved and maintain "an efficient, safe, and high-quality research and test reactor community… while the uranium enrichment is reduced" (Travelli et al. 1981). Historically, HEU-fueled reactors operated more efficiently when compared to LEU-fueled systems (Stahl 1982:1; Nunez 2020). Reduced-enrichment fuel research, therefore, took into consideration experimental capacity, economic viability in regards to core lifetime, conversion necessitated modifications to existing facilities, and reactor safety (Travelli 1980).

To achieve all of their objectives, the RERTR Program needed to generate thorough data showing the viability of LEU as used in an operating nuclear reactor. "The near-term object of the US RERTR Program is to demonstrate that the use of reduced-enrichment fuels meets the criteria of reliability, performance, safety, core lifetime, and economics. Two types of demonstrations are planned to meet this objective: fuel element irradiation testing and whole-core demonstrations. Data related to the first three criteria will come primarily from the element irradiations, whereas data related to the latter two, and, to some extent safety, will come from the whole-core demonstrations" (Snelgrove 1980). This objective was broken down into three phases: miniature fuel plate, or miniplate, fabrication, irradiation, and examination to select the best fuel candidates for the following phase; full-sized fuel element fabrication, irradiation, and examination using the most promising fuel determined in the first phase;

and, finally, a full-core demonstration utilizing the fuel type identified by the preceding phases (Travelli 1983).

The Program depended upon existing fuel fabrication technology to manufacture elements implementing new fuel technology exhibiting increased uranium densities; their aim in 1981 was to double the uranium density in LEU plate-type fuels every two years (Travelli 1980; Travelli et al. 1981). The Program planned irradiations at the ORR as well as at reactors located in the Netherlands, France, and Romania. The RERTR Program provided experimental fuel to these countries at no cost and shipped the spent fuel elements back to the United States for disposal (Snelgrove 1980). The ultimate goal was to "qualify" a new fuel for use in research and test reactors: "A fuel is considered qualified when a sufficient data base for the fuel exists that it can be approved by regulating bodies for use in reactors. To convert a core to the use of reduced-enrichment fuel it is necessary to show that the core will behave properly during normal and off-normal operating conditions and to show that the fuel will behave properly to a reasonable margin beyond the conditions expected during normal operation" (Snelgrove 1982).

At the ORR, work began with the first phase, or irradiating miniplates, before advancing to full-size elements. ORNL built an irradiation test facility, named the High-Uranium-Loaded Fuel Element Development (HFED). This facility, designed to fit into one of the core positions at the ORR and hold up to 60 miniplates simultaneously, allowed personnel to screen a multitude of potential fuel options, featuring a variety of fuel compositions, densities, and enrichments. ORNL commenced the first miniplate experiment, known as HFED-1 or HFED test 1, at the ORR on July 17, 1980. Once irradiated, staff removed the experiment during a scheduled shutdown and the elements were inspected in one of the hot cells at Building 3042 to detect any dimensional changes, indicating a potential leak of the fission products. The miniplate would then be reinserted into the reactor for further irradiation until the indicated exposure time had been accomplished. These fuel elements were sent back to their respective manufacturers for further examination. HFED-1, the initial LEU miniplate experiment at the ORR, concluded on June 13, 1983, after nearly three years of tests. The RERTR Program planned another series of miniplate irradiations to begin the following year. Ultimately, those fuel-plate types that proved successful would be reconstructed as full-sized fuel elements for testing in the ORR core (Snelgrove 1980; Senn and Martin 1981:1–4, 18, 26; Snelgrove et al. 1983). All miniplate irradiations for the RERTR Program, a total of 244 miniplates containing various candidate fuel materials, occurred in the HFED at the ORR. The final miniplates were removed from the ORR in January 1987 (Travelli 1986b:4; Senn 1989:1–12).

ANL fabricated uranium silicide miniplates for irradiation in the ORR beginning in the early 1980s. ORNL irradiated this fuel alongside other LEU fuel plate candidates with the HFED within the ORR core. RERTR Program scientists believed uranium silicides to be a promising dispersion fuel option due to their relatively high uranium density. The ORR was tasked with examining the fuels behavior, specifically "the interaction between the silicide particles and the aluminum matrix, the swelling behavior of the silicide particles, and the maximum volume fraction of silicide particles that could be contained in the aluminum matrix" (Hofman et al. 1983:1). Beginning in May 1982, six full-sized test elements had been irradiated in the ORR (Snelgrove 1984; Travelli 1982; Travelli et al. 1982).

The first full-sized, whole-core LEU demonstration occurred at the Ford Nuclear Reactor at the University of Michigan beginning in late 1981. These experiments provided the RERTR Program with reactor physics and operating data. By 1983, plans for a second whole-core demonstration at the ORR circulated utilizing a uranium silicide fuel. This demonstration aimed to collect data on LEU fuel's equilibrium-fuel-cycle characteristics, core physics, and fuel-cycle within about eighteen months of operation (Snelgrove and Copeland 1983). The Reactor Operations Review Committee (also known as the RORC) granted preliminary safety approval for the full-core demonstration in May 1984; final approval was contingent upon the results of the post-irradiation examinations of the six full-sized test elements. The DOE also approved ORNL's order of 100 LEU fuel elements and 12 control rod assemblies at that time (Snelgrove 1984).

The experiment at the ORR provided data not only on the use of a fully LEU core, but on the overall conversion process in regards to a relatively high-power research reactor. The RERTR Program planned for most research and test reactors to phase-in LEU elements over time. The ORR fuel cycle in the mid-1980s ranged from two to three weeks and each refueling introduced three or four fresh, or unirradiated, fuel elements to the core. The demonstration started in December 1985. The following month, personnel gradually began building toward a full LEU core, replacing spent HEU fuel elements with fresh LEU elements, creating a core composed of a mix of HEU and LEU elements. Assuming the longest cycle timeframe, staff estimated the entire transition process would take approximately 11 months and anticipated a full LEU core to be achieved by the end of the year. The six HEU control rods were also gradually replaced with LEU control rods, at the rate of two per quarter. ORNL achieved a full LEU core on December 10, 1986 (Snelgrove and Copeland 1983; Snelgrove 1984; Travelli 1985; Snelgrove et al. 1985; Hobbs et al. n.d.:1–3; Travelli 1986b:7; Travelli 1987:4).

The LEU whole-core demonstration at the ORR proved successful. Normal operating procedures continued uninhibited throughout the year-long experiment and safety margins exceeded both expectations and requirements (Hobbs et al. n.d.:17). The uranium silicide fuel cleared for qualification at the ORR could be used in the conversion of approximately 90% of the research and test reactors worldwide (Randolph 1986:viii). In November 1986, participants of the International Meeting on Reduced Enrichment for Research and Test Reactors, gathered in Gatlinburg, Tennessee, visited the ORR to witness the then-routine use of LEU fuel (Travelli 1986a:iii).

After the demonstration, the ORR operated with an entirely LEU reactor core for the rest of its service life. This period was unexpectedly brief. When the DOE issued shutdown orders for all of the ORNL reactors in March of 1987, the whole-core LEU fuel demonstration, planned to continue until September 1987, ended prematurely (Travelli 1987:4–5). Gene Muggridge, training manager for the BSR, recalled: "one of the experiments [at the ORR] that never completed was the experiment for the low enriched uranium cores, you know, when they'd made the decision to go with 20% enrichment? …. So we had the first core in that reactor and we were trying to get some data on it and when the shutdown come we didn't quite finish it…. So we never did… Never did get it finished" (Muggridge 2014:49). With the realization that the ORR would not be restarted within a reasonable timeframe, the RERTR Program leaders determined the goals of the ORR full-LEU-core demonstration to be met and the experiment was deemed concluded (Travelli 1987:5).

In 1986, during the whole-core LEU demonstration at the ORR, the Nuclear Regulatory Commission amended their regulations to require new reactors to use LEU fuel and existing reactors to begin plans for conversion to acceptable LEU fuel (Matos 1996:2). After the ORR was retired, the RERTR Program commenced additional LEU miniplate tests in the late 1990s at the Advanced Test Reactor at Idaho National Engineering Laboratory (Matos 1996:1).

All of the reactor conversions inherently depended upon the alignment of a multitude of variables, including politics, technology, and economics, not to mention the uniqueness of each reactor in its own right. Oftentimes, RERTR and its international partners acted opportunistically, taking advantage of political environments that may be short-lived, requiring the technical data to be available at a moment's notice. By the end of the twentieth century, after approximately 20 years of the RERTR Program, 30 reactors had been converted to LEU, including 10 in the United States, electing to lead by example. Most of these reactors easily converted to the uranium silicide dispersion fuel tested in the ORR and developed by ANL and ORNL. Remaining reactors fueled by HEU proved incapable of conversion to the uranium silicide fuel option due to anticipated unreasonable performance degradation. In 2001, after the September 11th attacks in New York City at the World Trade Center, the impetus to confine the dispersal of HEU heightened. The Global Threat Reduction Initiative (also known as the

GTRI) absorbed and fast-tracked the RERTR Program, now guided by the mission to “secure, remove, relocate, or dispose of radioactive materials as expeditiously as possible” (Nunez 2020). This required amplification of fuel development research in order to focus efforts on those reactors unable to accept the uranium silicide dispersion fuel (Nunez 2020).

As of 2020, this international collaboration had led to 71 reactors across almost 40 countries converting to LEU fuel. This included conversions of all the previously HEU-fueled reactors on the continents of South America, Australia, and Africa (Figure 222). An additional 31 research reactors previously fueled by HEU ceased operations and another 20 conversion projects were actively underway in 2020. Scientists also prepared to discover potential solutions to the high-power research reactors that annually employ hundreds of kilograms of HEU, including five in the United States and four in Europe. Conversion of these “crown jewels,” projected for the 2030s, will represent a substantial milestone for the RERTR (Nunez 2020). Although the ORR ceased operation before fulfilling its RERTR Program responsibilities, it contributed significantly to the success of the Program overall.

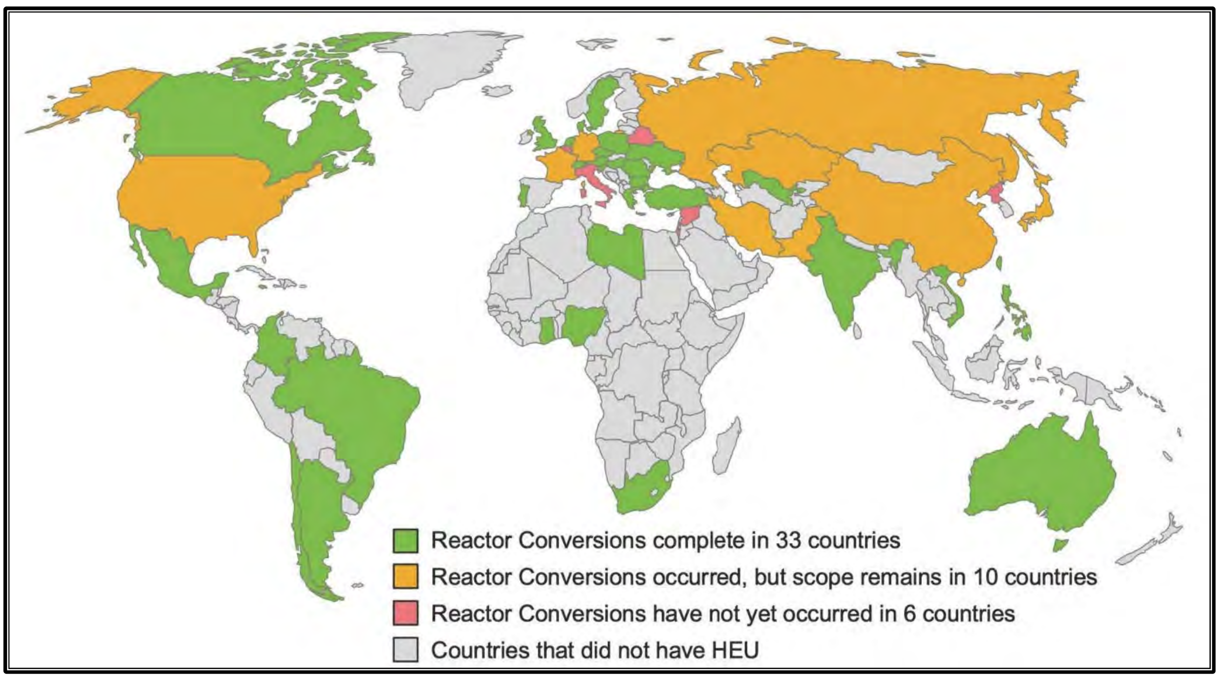

Figure 222. World map showing the status of reactor conversion from HEU to LEU fuel per country circa 2020 (Courtesy of Argonne National Laboratory) (Nunez 2020).

The Shutdown

During its nearly 30 years of operation, the ORR witnessed many changes at ORNL. The Department of Energy Act of 1977 established the DOE to replace the AEC, abolished by the Energy Reorganization Act of 1974. A few years later, in 1984, the contractor for ORNL changed from Union Carbide to Martin Marietta Energy Systems. In response to the incident in Chernobyl in April 1986, the DOE temporarily shut down all research reactors on March 26, 1987 in order to plan and execute needed managerial and procedural improvements. This included the ORR. This time period marked the first time in ORNL history that they lacked an operational nuclear reactor. In compliance with the DOE directive for an independent reactors division, ORNL officially established the RRD on April 6, 1987, and made A. L. Pete Lotts the first Director. As Lotts recalled, the DOE had concerns regarding the safety of the reactors at ORNL. His team, formed with the mission to restart all the reactors they considered feasible, selected to pursue continued operations of the TSR, HFIR, and ORR. Lotts and his team attempted to "prove to DOE, and the world, that they were fit to be operated and had a fit crew to operate them, so that was a job" (Lotts 2013:16).

According to Muggridge, who operated the BSR at the time of the shutdown:

> *We were down calibrating the control rods at the Bulk Shielding Reactor on Friday at four o'clock and we had one more control rod to calibrate and we got approval from the operators to work overtime on Friday… And, about four o'clock, the phone rang… it was Gary Coleman who was the operation manager for the Oak Ridge Research Reactor… He said, "Gene, you're going to have to shut down… we got orders from Joe LaGrone [DOE Oak Ridge operation head] … He's ordered all reactors to shut down immediately." I said, "Wait a minute, Gary… I got one more control rod to calibrate… When I get through with that, we'll shut down." He said, "No, you won't… You shut down right now… And take the key out." And I said "You serious?" And so, we talked a little bit and realized this was serious. And so we shut the reactor down and pulled the keys out… And so we shut down and that was the end of the reactors… everybody was frustrated, you know. And there was a lot of hullabaloo going on… management started trying to regroup under DOE's direction, and so, DOE said, "Well, what we need is a quality assurance plan for each reactor you want to start."* [Muggridge 2014:47–49].

Muggridge, therefore, assembled a team. The first quality assurance plan they drafted was for the ORR, as the shutdown interrupted the isotope production there, and several other ORR experiments were left incomplete, including the LEU whole-core experiment under the RERTR Program. At over two hundred pages, this quality assurance plan addressed the safety system, which Muggridge's team thoroughly inspected. The same team subsequently wrote the quality assurance plan for the BSR. Ultimately, the DOE rejected the requests to restart both the BSR and ORR (Muggridge 2014:48–52).

On July 14, 1987, ORNL received the official directive from the DOE to shut down ORR operations permanently, and by 1992 the BSR, PCA, and HPRR were all permanently shut down as well. The RRD expanded personnel and divisional sections through 1987 and 1988. In 1989, the RRD began restarting and repowering the ORNL reactors approved for re-operation by the DOE (Coleman and Laughlin 1989:4; Rogers 2018:3, 10–16, 31–33; Rosenthal 2010:46). In Europe, Switzerland discontinued use of the Geneva Reactor in 1994 (Rosenthal 2010:60).

A Tourist Attraction

The ORR left a legacy that stretched beyond the scientific community. Captivated by the mysterious "blue glow," the ORR became a tourist attraction for visiting domestic and foreign political figures. This blue glow, caused by nuclear fission in water, was due to the Cerenkov effect, named after the Russian physicist, Pavel Cerenkov, who first witnessed that water "irradiated with gamma rays emitted a weak bluish-white glow" in 1934 (Jordan 1951:54). The LITR made international history by being the site of the first photograph ever taken of the Cerenkov effect during a mockup experiment in 1950. *Scientific American* published this photograph on the cover of their October 1951 issue, making both ORNL and the LITR famous for reactor technology worldwide (Johnson and Schaffer 1992c:64; Front Matter 1951). "On the cover of this issue … is an historic picture. It is the first photograph to show the interior of a nuclear chain reactor in actual operation. Suffusing the reactor, which is located at Oak Ridge National Laboratory in Oak Ridge, Tenn., is a curious blue glow; indeed, the reactor is photographed by its own light … The most brilliant display is observed when an entire reactor is operated in a tank of water; the photograph on the cover was made under such conditions" (Jordan 1951:54–55).

In 1955, ORNL would take their "blue glow" show on the road when they designed, shipped, and reconstructed the Geneva Reactor at the United Nations International Conference on the Peaceful Uses of Atomic Energy. The Aquarium Reactor exhibit became the most popular at the conference, entertaining royalty, world leaders, and dignitaries with its blue glow. Many of these renowned guests even operated the reactor. In total, over 62,000 people viewed the ORNL reactor. One of the attendees, Laura Capon Fermi, the Official Historian of the Conference and wife of Italian physicist Enrico Fermi, referred to it as the world's "most beautiful little reactor" (see Figure 154) (Johnson and Schaffer 1992d:107). In October 1955, the Geneva Reactor made the cover of *Scientific American* (Front Matter 1955).

After the international fame ORNL earned with both the LITR and Geneva Reactor, the Cerenkov glow continued to instill quite a bit of interest. The Cerenkov glow also emanated from the BSR and, after construction completed in 1958, the ORR. The ORR attracted spectators not only due to the mesmerizing blue glow, but in the late 1950s and early to mid-1960s research reactors were still a novelty. Being the most powerful research reactor in the world at the time, the ORR was particularly alluring. Due to President Eisenhower's Atoms for Peace initiative, security at ORNL relaxed and allowed for scientists, engineers, politicians, and even foreign dignitaries to tour the ORR. The reactor became "a standard stop on all VIP tours of the Laboratory" (Johnson and Schaffer 1992d:103–105).

Scientists, politicians, kings, queens, and future U.S. presidents visited the ORR in the late 1950s and through the 1960s. This list included: Senator and future President Lyndon Johnson in 1958, U.S. Representative and future President Gerald Ford in 1965, Vice President Hubert Humphrey in 1965, Senator John Pastore in 1963, King Leopold of Belgium in 1957, King Bhumibol Adulyadej of Thailand in 1960, King Hussein of Jordan in 1959, Indian ambassador Indira Nehru in 1963 (later the Prime Minister Indira Ghandi), Prime Minister of Afghanistan Sardor Mohammed Davd in 1958, Premier of Northern Nigeria Sir Ahmadu Bellow in 1960, leaders of the Soviet Union Laboratory and Soviet Academy of Science in 1959, and Nobel Laureate Glenn Seaborg in 1963 (Johnson and Schaffer 1992d:102-103; Cabage 2000:4). The first queen to ever visit ORNL, Queen Frederika of Greece, toured the ORR in 1958. The ORNL News noted at the time that she "revealed a keen sense of knowledge of the nuclear energy field in her conversations with ORNL scientists" (Figures 223–225) (Johnson and Schaffer 1992d:103)

Possibly the most famous visitor to the ORR, Senator and future president John F. Kennedy and future First Lady Jacqueline toured ORNL on February 24, 1959 with Senator Albert Gore Sr., Weinberg, and John Swartout, the Deputy Director of ORNL. Prior to his visit, Kennedy announced to a few hundred people at Grove Center's Oak Terrace Restaurant in Oak Ridge that he planned to run for president in 1960. He visited ORNL in order to support peaceful uses of atomic energy, a cause Senator Gore was known to advocate for as well. At the restaurant, Kennedy asserted: "Here in Oak Ridge this nation has demonstrated the vast power which results from the combination of many talents and resources—abundant power, scientific personnel, industrial capabilities, fuel supplies, and zealous government administration" (Figure 226) (Johnson and Schaffer 1992d:102).

Access to the ORR was not limited to only famous visitors. Dewie Bilbrey, a schoolteacher at Oak Ridge High School from 1957 until 1994, conducted Saturday tours at ORNL for about 30 years starting in 1961. These tour groups, comprised of the general public or school students, visited the Graphite

Reactor and other places as they were made available to them. Bilbrey recalled that, once the ORR came "on line," they began taking groups to Building 3042: "believe it or not, I have seen as many as 50 students gathered around that pool… you look down through the water and saw the Cerenkov glow, which was very mysterious at that time" (Bilbrey 2013:39-42). In total, dozens if not hundreds of visitors, including politicians, royalty, celebrities, and even schoolchildren, many of whom lacked a scientific background, toured the ORR. This reactor thusly became representative for research reactors worldwide, particularly for those who may have only witnessed one operating reactor in their lifetime.

Figure 223. Archival photograph showing Tennessee Governor Buford Ellington (left), then Texas Senator Lyndon Johnson (third from left), and Tennessee Senator Albert Gore Senior (second from right) looking over the ORR pool, circa 1958 (ORNL Photo 58-930).

Figure 224. Archival photograph showing King Hussein of Jordan operating the remote manipulators at the ORR, March 30, 1959 (ORNL Photo 59-239-16).

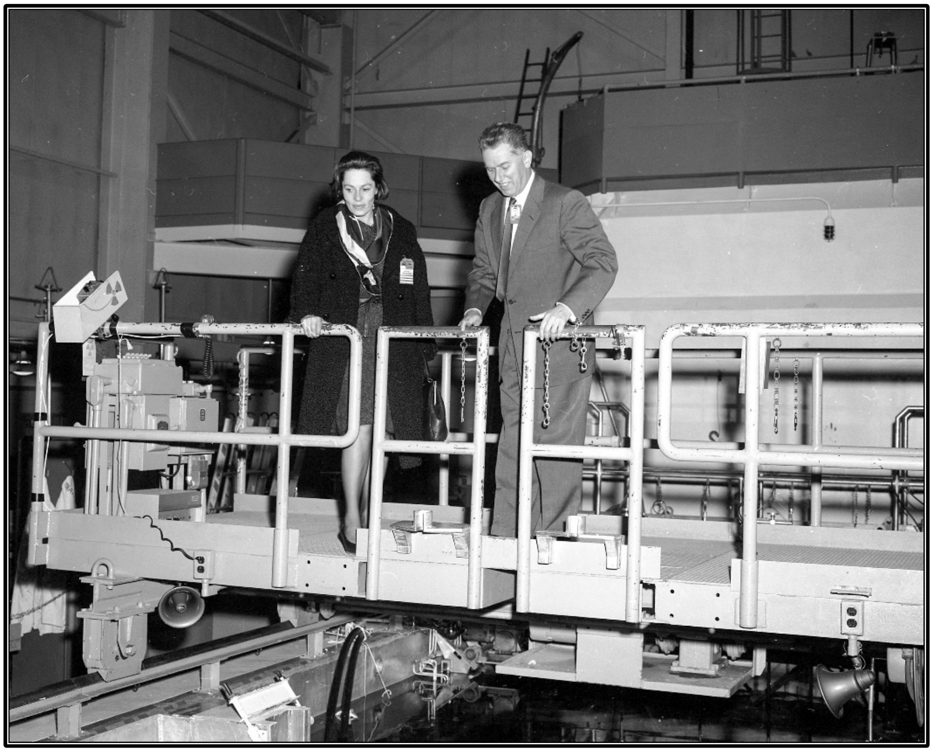

Figure 225. Archival photograph showing Swedish actress Viveca Lindfors touring the ORR while in town for an Oak Ridge Arts Council presentation, circa March 1965 (ORNL Photo 130971).

Figure 226. Archival photograph showing Weinberg (third from left) with then Massachusetts Senator John F. Kennedy (second from left), Tennessee Senator Albert Gore Senior (third from right), and Jacqueline Kennedy (second from right), circa February 1959. Weinberg is seen directing the visitors' attention toward the ORR (ORNL Photo 4786).

SIGNIFICANCE

The ORR represents the confluence of substantial advances in nuclear reactor technology at ORNL in the 1950s. Utilizing the swimming-pool reactor design of the BSR as well as the high neutron flux of the MTR, the ORR provided the scientific community with a flexible and high-power reactor in a convenient location for research and experimentation. The ORR inspired the construction of a similar material testing reactor in Sweden even before construction was completed (Libby et al. 1957:23). Additional reactors inspired by the design of the ORR were constructed in South Africa, France, and the Netherlands. Throughout its service life, the ORR contributed to advances in numerous fields of science, including neutron scattering, reactor engineering, basic and applied physics, metallurgy, chemistry, and biology. The ORR also generated more radioisotopes for research, medical, and industrial uses than any other reactor in the world while it remained operational.

The interior and exterior of Building 3042, housing the ORR, retains notable integrity as the only substantial addition to the facility occurred during its construction. Minor exterior additions occurred throughout its service life, all of which were comprised of similar materials to the original structure. These additions also relate to the building's mission history and date to the period of significance. As such, Building 3042 is a contributing feature of the ORNL Historic District, as first proposed by Duvall & Associates in 1994 (Carver and Slater 1994:355–356).

Thus, Building 3042 is determined eligible for listing in the NRHP under Criterion A as a contributing facility of the previously proposed ORNL Historic District for "its development as a national laboratory within the overall post-World War II government sponsored-scientific movement, and early nuclear research" (Carver and Slater 1994:39). Housing a uniquely high-powered and accessible research reactor renowned the world over at the time of its construction, Building 3042 is eligible under Criterion C for pioneering the specific engineering requirements necessitated for the operation of a high-powered, water-moderated reactor, and for its substantial contributions to scientific research and development across many fields.

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