A Brief History of the *Research Reactors Division* of Oak Ridge National Laboratory

ORNUM-2342

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of the
Research Reactors Division
of
Oak Ridge National Laboratory

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC06-84OR21400

Acknowledgments

Sincere thanks to all those who provided information for this history through interviews, pictures, and documents. A special thanks to Tom Cole and Reuben McCord, Martin Marietta Energy Systems retirees, for their valuable interviews and information. The history of this division was compiled from sources too numerous to list; however, each of their valuable contributions is appreciated.

Introduction

The Research Reactors Division was officially chartered as an entity on April 6, 1987; however, the work of the division actually began in 1943 with the construction of Clinton Laboratories and the Graphite Reactor. The 50th year celebration of Oak Ridge National Laboratory (ORNL) exists in part because of the efforts of many people who came to Oak Ridge in the early 1940s and later became members of the Reactor Operations Department of the Operations Division and eventually the Research Reactors Division. The division's roots began with the Oak Ridge Graphite Reactor and the Low-Intensity Test Reactor (LITR) and have grown to include the Critical Experiments Facility (CEF), Bulk Shielding Reactor (BSR), Pool Critical Assembly (PCA), Oak Ridge Research Reactor (ORR), Tower Shielding Reactor II (TSR-II), Health Physics Research Reactor (HPRR), and the High Flux Isotope Reactor (HFIR). The Research Reactors Division has seen many exciting developments and events over the past 50 years, including the design and construction of the reactors, worldwide recognition for experiments and research, visiting dignitaries from around the world, the shutdown in 1987, and the challenging climb back to restart and power operation in 1989.

The following brief history begins with a look at the past 50 years in general, from the early years of dormitories and dirt roads to the present day of compliance and regulation. It concludes with a look at each reactor and its historical significance to ORNL.

The Forties Through Nineties

Clinton Engineer Works, a military reservation developed under President Roosevelt's Manhattan Project, began in 1943. Clinton Laboratories (the ORNL complex) and the Oak Ridge Graphite Reactor were born from this top-secret project whose mission was to produce gram quantities of plutonium for developing chemical separation processes to separate plutonium from other elements. Clinton Laboratories' purpose was somewhat separate-to provide for early scaling-up of the University of Chicago's Metallurgical Laboratory's initial neutron chain reaction and microchemical separation of plutonium. In this respect, the X- 10 pile and associated chemical process plant were pilot plants for the Hanford plutonium production complex. Along with developing and testing the processes, Clinton Laboratories was to produce gram quantities of plutonium for physical and chemical tests.

The first step in developing these important aspects of the Manhattan Project was to find a suitable location for them. An east Tennessee area was selected and was to include two production sites and a reactor/ pilot plant site on approximately 59,000 acres of farmland. At the end of 1942, the relatively few resident families were removed from this farmland and preparation was made to provide the transportation, communications, and utility needs of the town and production plants. Originally, Clinton Engineer Works was to house approximately 13,000 people in trailers, prefabricated housing, and wood dormitories. By the time the Manhattan Engineer District headquarters were moved to the area, estimates for the new town had grown to nearly 45,000 people. Eventually a town was formed and it was named Oak Ridge.

Personnel for the new project consisted of E. I. du Pont de Nemours and Company, Inc., employees, students and faculty members from universities, and native Tennesseans. Most people were sent to the Laboratory with no idea of the type of work they would be doing. Reuben McCord was one of those people. McCord, a DuPont employee, was transferred from the Manhattan Project's Metallurgical Laboratory at the University of Chicago to Tennessee on May 7, 1943. He was the 15th DuPont employee to receive an operating badge at Clinton Laboratories. McCord was told no details about his new assignment, only that he was going to work in Tennessee and that his work there would be highly secret. Upon arriving at Clinton Engineer Works, McCord checked in at the administrative building, which was an old farmhouse at the entrance to the Laboratory. The adjoining city consisted of dormitories and dirt roads-no houses or paved streets.

In the early years, the only major divisions at Clinton Laboratories were the Physics Division, the Chemistry Division, and a small Biology Division. The Physics Division was responsible for the Graphite Reactor, and the Chemistry Division was responsible for checking the chemical processes for the reactor. Additional research and operational functions, including development of the Low-Intensity Test Reactor at the Laboratory, increased the need for a separate division to handle Laboratory operations. Thus, the Operations Division was created with Logan Emlet as the director. As the division grew, Emlet became a Laboratory executive director, Mansel Ramsey was the Operations Division director, and Jim Cox was named the Reactor Operations Department supervisor.

Until the end of World War II, a top priority at the Laboratory was secrecy. According to McCord, there was little, if any, contact with people in other divisions or sections. Employees were told not to pay attention to what others were working on and to communicate only with people in their section.

Radiation-protection practices in the 1940s and 1950s were quite different from today's standards because the field of radiation protection was developing in parallel to the technology. The allowable radiation dose at that time was 500 millirem per week. Badge dosimeters did not exist, and pocket meters were not very accurate and were easily broken. One employee remembers removing isotopes from the Graphite Reactor by grabbing the isotope cans with tongs and carrying them to an open lead safe. Radiation alarms sounded as the isotopes were removed from the reactor; however, this was an accepted practice at the time. It was a very crude but effective way of removing the isotopes.

Interaction with the government was also very different in the early years. On January 1, 1947, in accordance with the Atomic Energy Act of 1946, all atomic energy activities were transferred from the Manhattan Engineer District to the newly created U.S. Atomic Energy Commission (AEC). The Manhattan Engineer District was then abolished on August 15, 1947. The AEC operated with a hands-off management style in which the Laboratory director made most technical decisions. Reactor employees had little interaction with the AEC until the AEC later changed its philosophy and became more involved in activities at the Laboratory. The AEC was eventually abolished. The Energy Research and Development Administration acted as an interim agency until the Department of Energy (DOE) was formed in the 1970s.

The 1950s brought major developments in reactor operations at the newly named Oak Ridge National Laboratory. The Laboratory and its reactors were virtually the sole source of isotopes for the free world. The Graphite Reactor continued to operate, the Critical Experiments Facility began its critical and noncritical experiments in 1950; the LITR and the BSR started up in 195 1; and the ORR went critical in March 1958. The Tower Shielding Facility (TSF) was built in 1954; and by the end of the decade plans were being made to design, build, and operate a reactor of even higher flux. Many Operations Division personnel were actively involved in the design and construction of each of these major research reactor projects.

The Sixties

The 1960s were prosperous years for the Operations Division's Reactor Operations Section. Jim Cox replaced Manse1 Ramsey as Operations Division Director, and Reuben McCord was named Reactor Operations Section manager. The Oak Ridge Graphite Reactor continued to run until late 1963, and the LITR operated until October 1968. As these two reactors were shut down, the BSR became a general-purpose research reactor. The ORR continued to operate successfully and gained worldwide fame. In 1960, the TSR-II, a spherically symmetrical l-megawatt reactor, was installed at the TSF as a replacement for the Tower Shielding Reactor I.

The HPRR was designed at ORNL and constructed under the Laboratory's supervision. Following initial tests in the CEF it was loaned to Operation Bare Reactor Experiment Nevada (BREN) at the Nevada

Test Site. After its use there it was returned to ORNL in 1963. This new reactor was deployed for health physics and dosimetry applications.

The HFIR, one of the world's most powerful research reactors, began full-power operation in 1966.

The Seventies

ORNL was involved in design studies of advanced reactors for electric power generation and in studies relating to the improvement of reactor safety during the 1970s. During this decade, the emphasis of research missions was shifted to alternative energy forms and the environmental and health impacts of energy production and use.

The Reactor Operations Section, still headed by McCord, included the HFIR, ORR, BSR/PCA, TSR-II, and HPRR. These reactors could be classified into two groups. The HFIR, ORR, and BSR/PCA were in one group because of their mode of continuous operation, whereas the TSR-II and HPRR ran only during experiments and at specified times of the day. However, it was important that all of these reactors be under the same management group so that only one group would be responsible for dealing with reactor issues. The Operations Division, with Cox as director, had become a widely diverse division with many important Laboratory functions; thus, the need for a separate division whose sole purpose would be to operate and run the research reactors was becoming apparent.

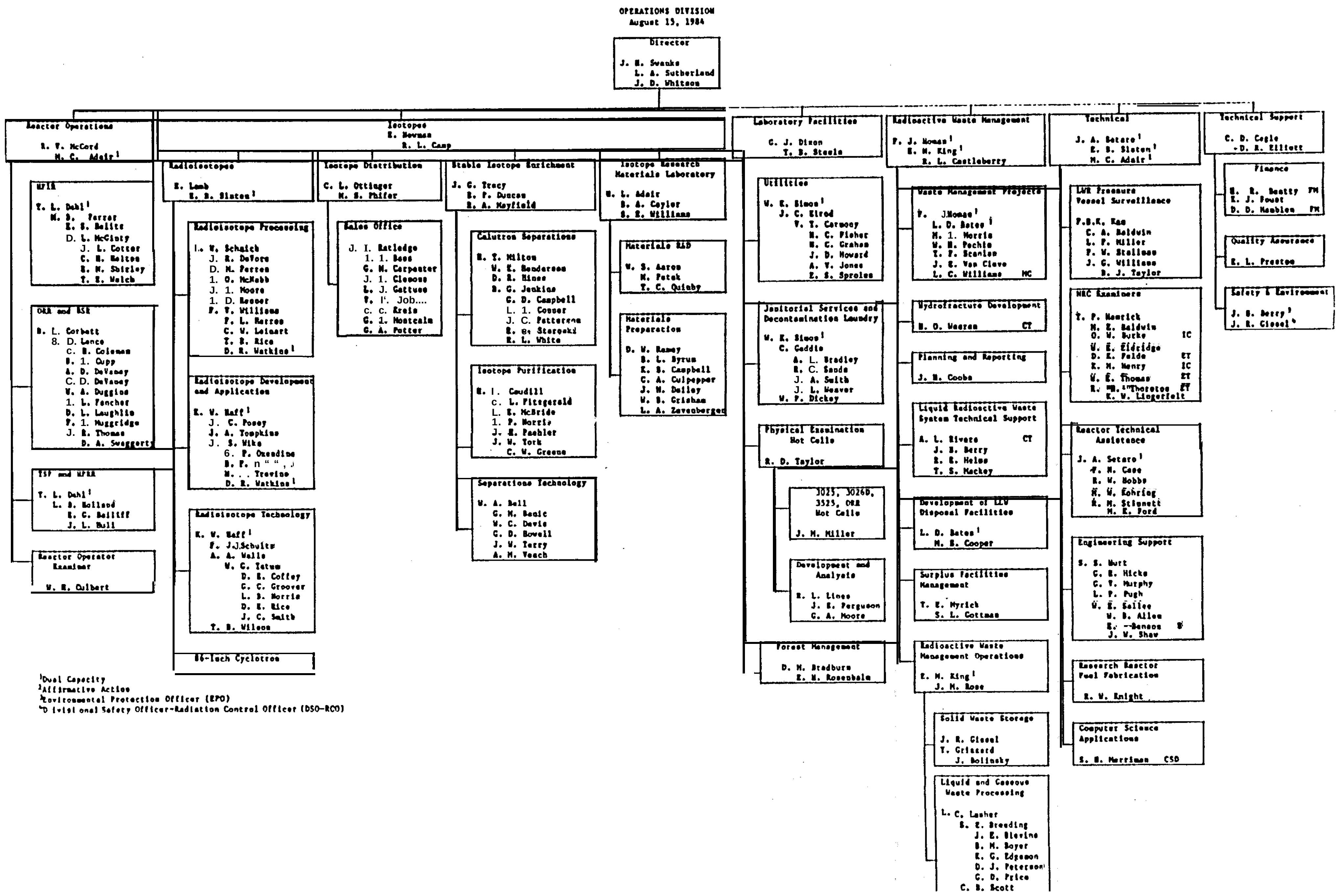
The Eighties

As the 1980s began, the operating reactors assumed the role of user facilities. Jerry Swanks was director of the Operations Division, and Reuben McCord was head of the Reactors Section. ORNL's reactors were made available for specialized research by qualified industries and other government agencies. The reactors were used as radiation sources for biological and physical sciences research and for services such as neutron activation analysis and criticality alarm calibration. During this time, ORNL's reactors remained the sole free-world sources for some radioisotopes for medical and industrial research even though most isotope production had been shifted to private industry.

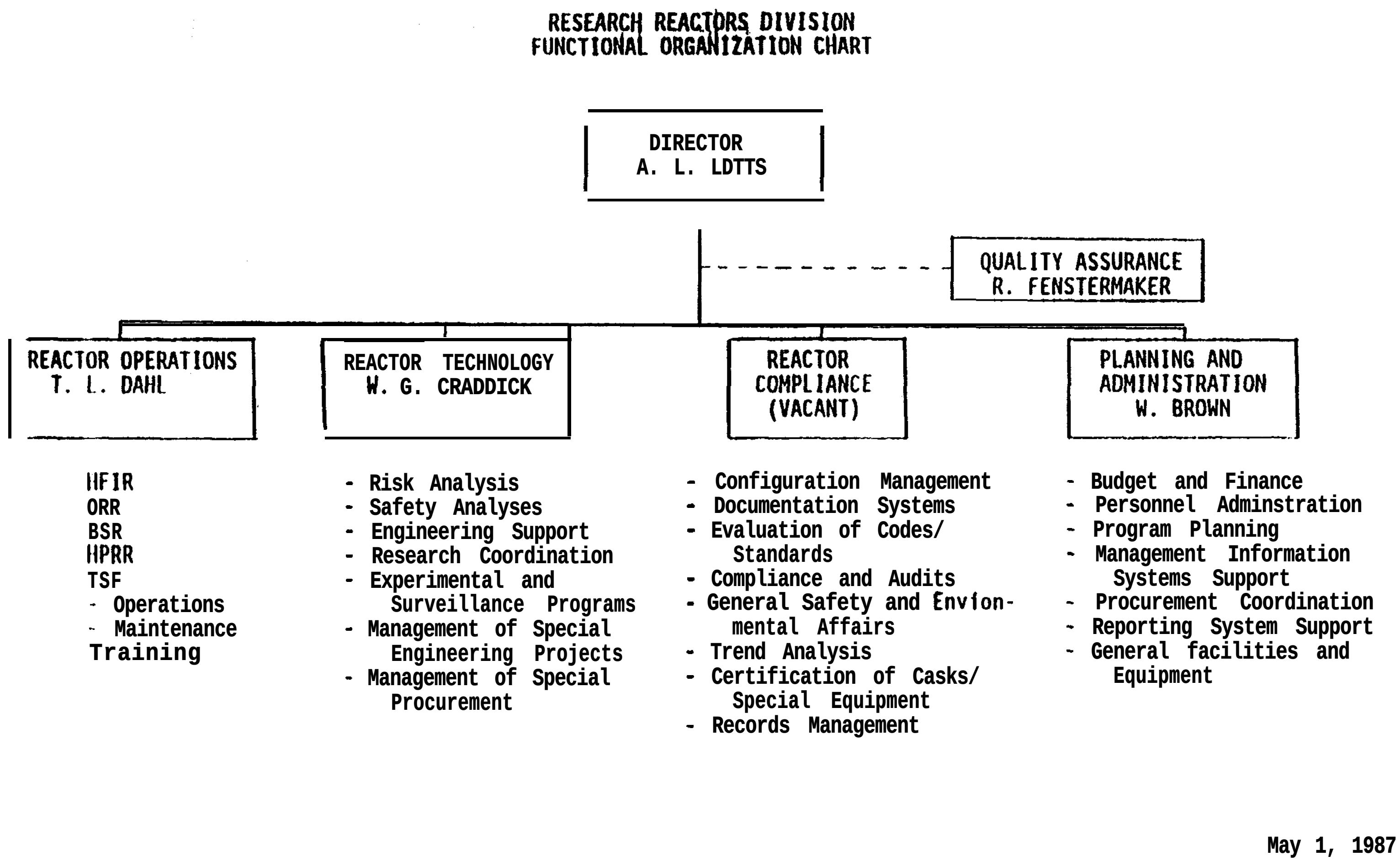
In the middle to late 1980s, after the Three Mile Island and Chernobyl incidents, ORNL began internal reviews, led by Don Trauger, of all its research reactors to determine potential safety deficiencies and corrective actions. These reviews eventually led to the shutdown of the HFIR in November 1986. Additional internal and external reviews of the HFIR, ORNL, and Martin Marietta Energy Systems, led to DOE's order that all ORNL research reactors be shut down in March 1987 until needed improvements, primarily in management and procedures, could be made. For the first time in its history, the Laboratory had no nuclear reactors in operation.

ORNL's first step toward recovery from the shutdown of all its research reactors was a management realignment. A group devoted solely to operating the reactors was needed. The Operations Division had too little funding and too many other responsibilities, including the Isotopes Program, ORNI. Utilities, and Waste Management, to devote the necessary time and attention to the reactors. DOE suggested that a high-level manager be appointed to oversee ORNL Reactor Operations and help restore the Laboratory's credibility in this area. As a result, Fred Mynatt was designated ORNL's Associate Director for Reactor Systems.

In compliance with DOE's mandate for a separate reactors division, the Research Reactors Division (RRD) was chartered on April 6, 1987, with A. L. "Pete" Lotts named



The Reactor Operations Section as part of the Operations Division.



RRD's first organization chart.

as' division director. The Reactor Operations Section and most of the technical staff of the Operations Division formed the new division. According to Lotts, the primary goal of this new division was "to build a sound reactor operations organization and to restore the reactors to operation." RRD was made responsible for all operating or standby research reactors at ORNL. Several sections were formed in the new division, including Reactor Operations, Reactor Technology, Reactor Compliance, and Planning and Administration. A section of ORNL's Quality Assurance Division was also assigned to RRD.

Because of a lack of office space, the division was originally housed in several areas of the Laboratory. One group was located in a laboratory in Building 4508, another in labs in Building 4500-S, some in the new High Temperature Materials Laboratory (HTML) building. The division director and support staff were located in the basement of Building 4508. In the spring of 1988, all personnel were relocated to the HFIR site in various trailers and buildings, including the new Solid State Division office building, Building 7962. At the time of the move, a strike by the Atomic Trades and Labor Council had everyone pitching in to fill the gap left by the striking union members. More trailers were eventually located at the HFIR site, and RRD personnel in Building 7962 were relocated again to several trailers close to the HFIR.

The intense political visibility of reactor operations necessitated an additional level of upper management that would report directly to the president of Energy Systems. In April 1988, Robert Montross, ex-Navy nuclear submarine officer and commercial utility plant manager, was hired as director of Reactor Operations. He worked as liaison with Fred Mynatt and reported directly to Clyde Hopkins, current president of Energy Systems. Montross was succeeded in October 1988 by Jackson Richard, ex-Navy nuclear submarine officer and commercial nuclear utility executive. Mynatt and Richard both reported to Herman Postma, then director of ORNL, while Richard additionally reported directly to Clyde Hopkins president of Energy Systems. RRD continued to expand its personnel adding two new sections to the division. The B Reactors Section was created to include the BSR, HPRR, ORR, and TSR-II. A Training Section was also formed to handle the many training requirements of the division.

During this time, RRD was reviewed by numerous committees from DOE and Energy Systems and by independent consultants. Some of these committees, such as the Independent Review Committee (IRC), now named the Research Reactors Review Committee (RRRC), and the Reactor Operations Review Committee (RORC), still provide input into reactor operations. After much review and scrutinizing of the reactors, the committees agreed that the HFIR should restart provided certain conditions were met. However, these conditions were very extensive, and time would be needed to meet all of the new requirements. RRD employees, as well as many people from other divisions, spent countless hours meeting requirements set to restart the HFIR. Staff meetings were held daily to review the plan of the day and discuss upcoming reviews or potential problems. Finally, U.S. Secretary of Energy Admiral James Watkins announced his approval for the HFIR's official restart. Initial restart occurred on April 18, 1989. However, on May 9, 1989, while it was operating at a level of 10 MW, the HFIR was inadvertently shut down just moments before the planned time for shutdown. The reactor remained idle for months while aspects of this operational error were addressed. In August 1989 Pete Lotts retired from Energy Systems and H. A. “Hal” Glovier, ex-Navy nuclear submariner, utility executive and plant manager, and previously associate division director, was named division director. Walt Brown, former Planning and Administration and later Management Systems Support Section manager, was named associate division director. On January 29, 1990, after receiving DOE permission, ORNL resumed operation of the I-FIR at an initial power level of 8.5 MW.

The Nineties

In the early 1990s the trailers at the HFIR became overcrowded as more personnel were hired to meet increasing demands. In July 1990 the administration and the Training, Compliance, part of Reactor Technology, and the Category B Reactors sections moved into a new 14,000-ft^2 office building across the street from the HFIR. The trailers now house additional technical staff as well as the DOE-OR Reactor Operations Division.

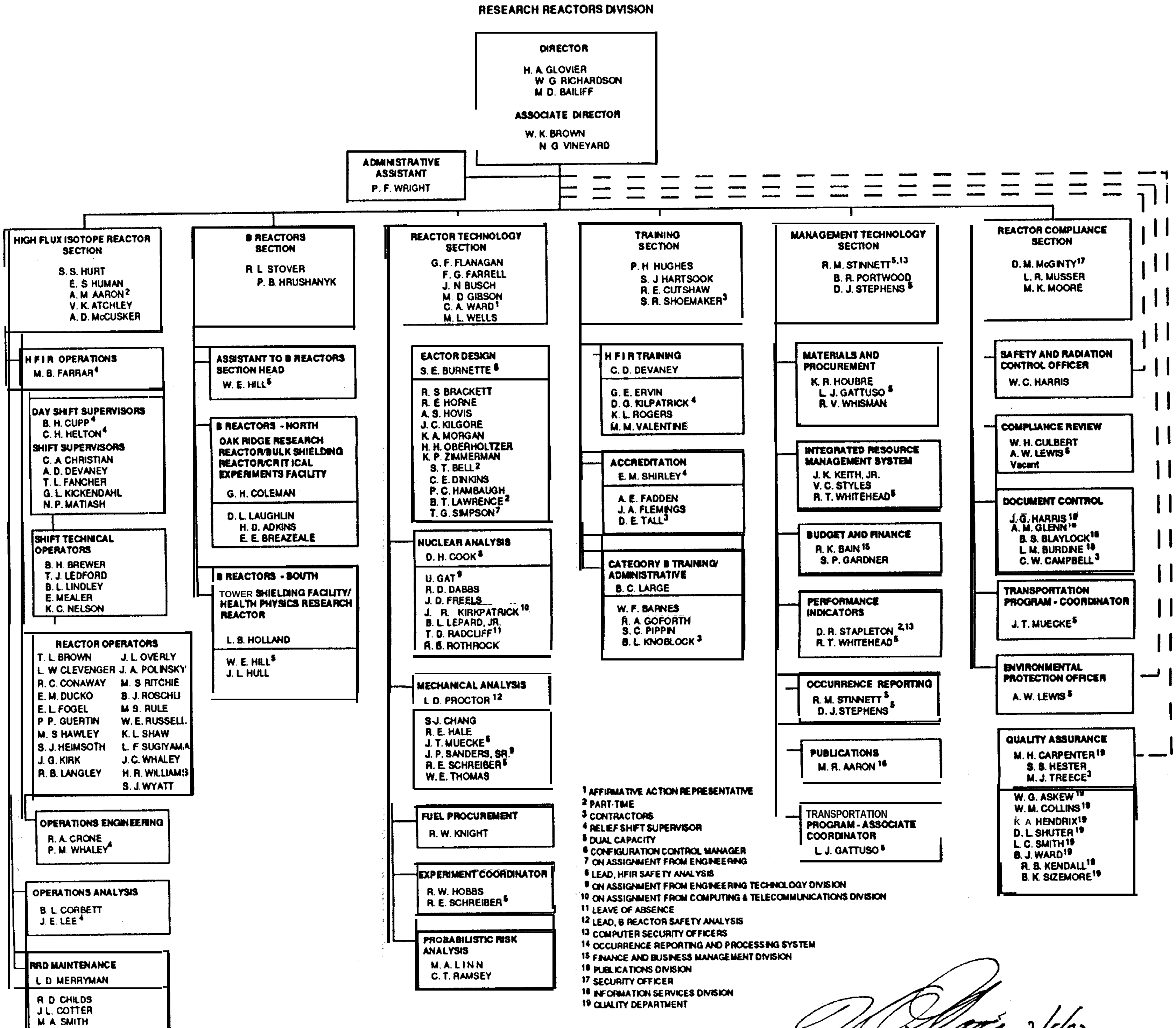
Since initial establishment in 1987, the new reactors division has grown to include six sections, including excellent people from other ORNL divisions, from within Energy Systems, and from outside ORNL. Areas such as probabilistic risk assessment (PRA), seismic analysis, compliance, training, quality assurance, and new management systems based on well-founded principles of documented policies and procedures have been put into place in RRD.

The HFIR has operated at full power for most of the time since restart with many innovative and exciting experiments being performed. The biggest challenge facing the HFIR now is finding a solution to the spent fuel storage problem. By 1994, no space will be left in the HFIR pool for storing fuel elements that have completed a cycle in the reactor and are now depleted. RRD personnel are working to find new ways of storage until an approved spent fuel shipping cask is available and the fuel elements can be shipped to another facility for storage or recycling.

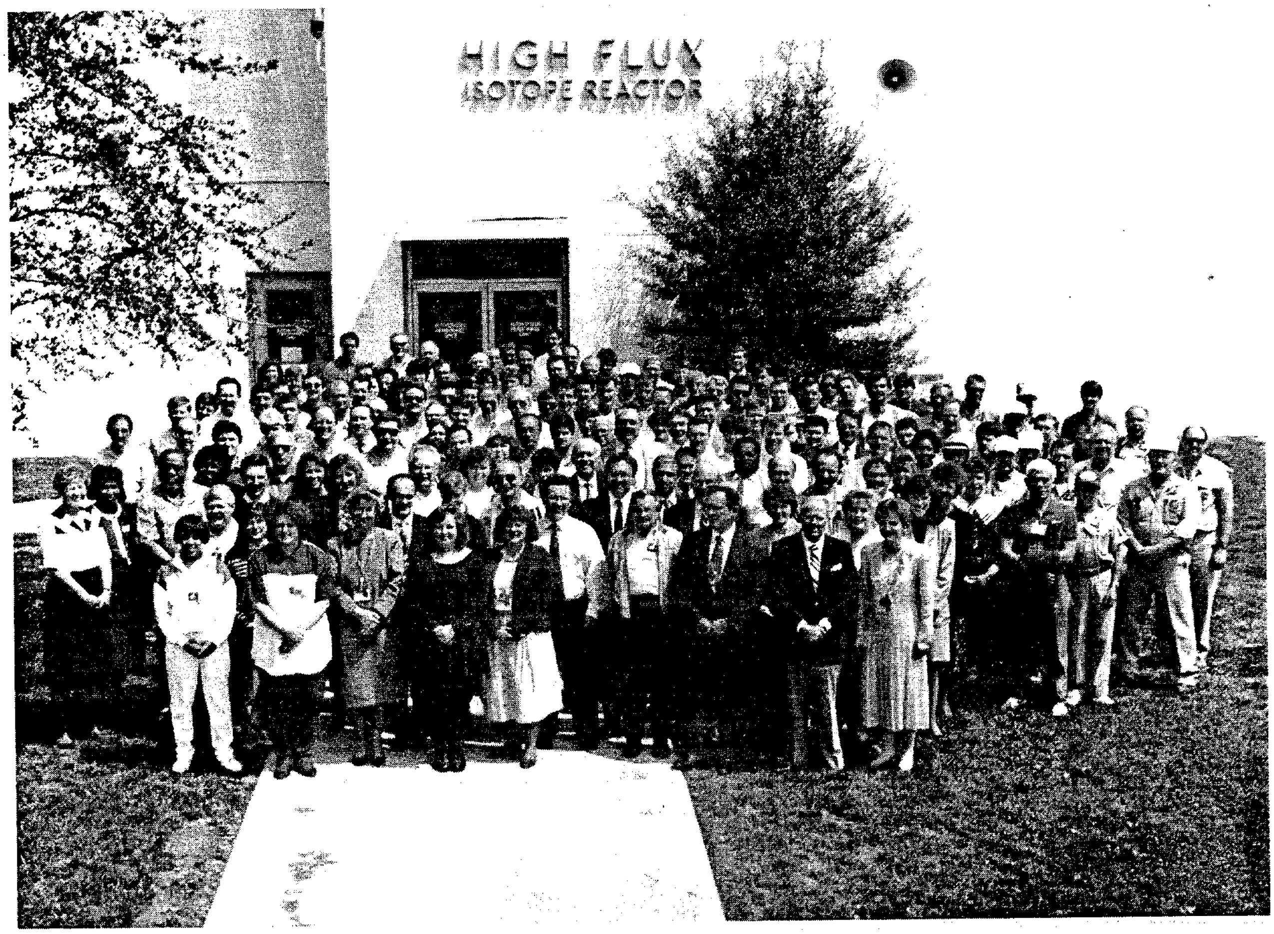
A facility shutdown plan for the HPRR has been submitted to DOE for approval. The HPRR was permanently shut down because of safeguards and security concerns. The BSR and ORR are also permanently shut down. A permanent shutdown plan will be submitted for the BSR by the end of summer 1992. The ORR will be transferred to the Office of Waste Management and Remedial Action at the end of FY 1992.

The TSR-II continues to operate for the Japanese-American Shielding Program for Experimental Research (JASPER); however, this program is scheduled for completion at the end of 1992. The B Reactors Section and ORNL management arc currently trying to find new uses for the TSR-II.

The objective of RRD continues to be “to approach and exceed currently accepted standards for Conduct of Operations.” As technological innovations continue, the need for new research reactors continues to grow. ORNL is now in the design phase for a new reactor, the Advanced Neutron Source (ANS), which will be the world’s most powerful source of neutrons for research. However, it is important to remember the history of the older research reactors. Each of these reactors has made a unique contribution in the world of research and experimentation that has set the stage for the future.



RRD organization chart, 1992.



RRD personnel, 1992.

Oak Ridge Graphite Reactor

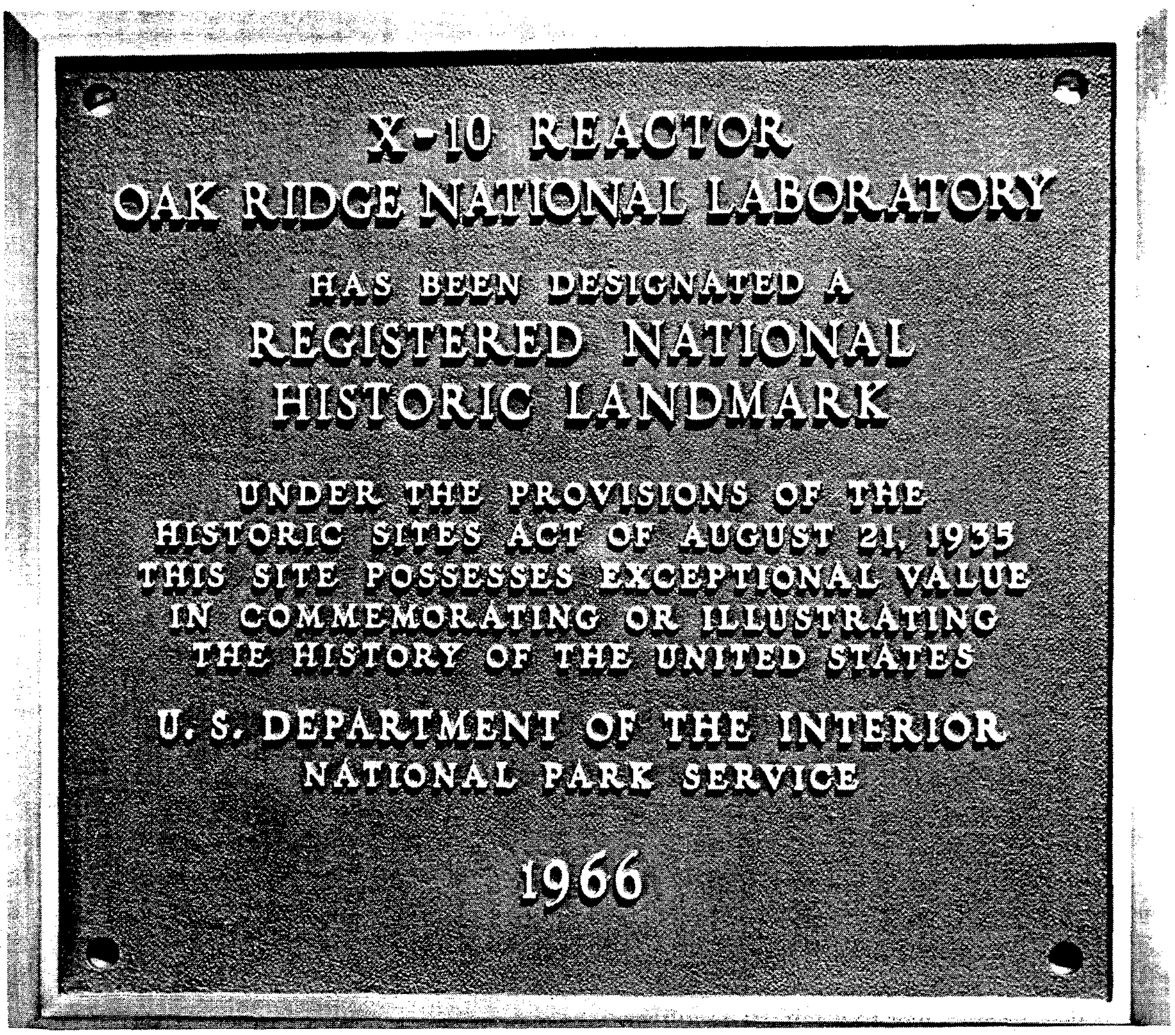
Now a national historic landmark, the Oak Ridge Graphite Reactor was built in only 11 months as part of the World War II Manhattan Project and operated 20 years from November 4, 1943, to November 4, 1963. The reactor was the result of a major national effort to produce fission bombs and is the world's oldest nuclear reactor.

After it was determined that a nuclear chain reaction could. be self-sustaining and controlled, construction of a &clear reactor to produce gram quantities of plutonium for a chemical separating pilot plant began. Land was acquired in 1942 between Clinton, Kingston, and Oliver Springs, Tennessee, under the pretense, for security reasons, of establishing the Kingston Demolition Range. The Army Corps of Engineers started construction of a town (Oak Ridge) and administrative office buildings in 1942 under the name Clinton Engineer Works. The mission of Clinton Laboratories, as ORNL was then known, was to establish a pilot plant for the Hanford, Washington, reactor; to carry out necessary research and development for large-scale plutonium production; as well as to supply the first gram quantities of purified plutonium. The Graphite Reactor was completed on October 16, 1943, and on November 3 at 4:30 p.m., the loading of fuel slugs into the reactor was begun under the supervision of Enrico Fermi. The reactor went critical on November 4, 1943, after 30 tons of uranium had been loaded.

Research facilities in the Graphite Reactor could accommodate more than 36 experiments and expose 1000 samples or target materials simultaneously for radioisotope production. Over the years, samples from industry were irradiated, such as piston rings, cylinder liners, and other items. Tunnels for irradiation of biological specimens were also available to researchers and were used for irradiating soy beans, popcorn, and peanut seeds for mutation studies.

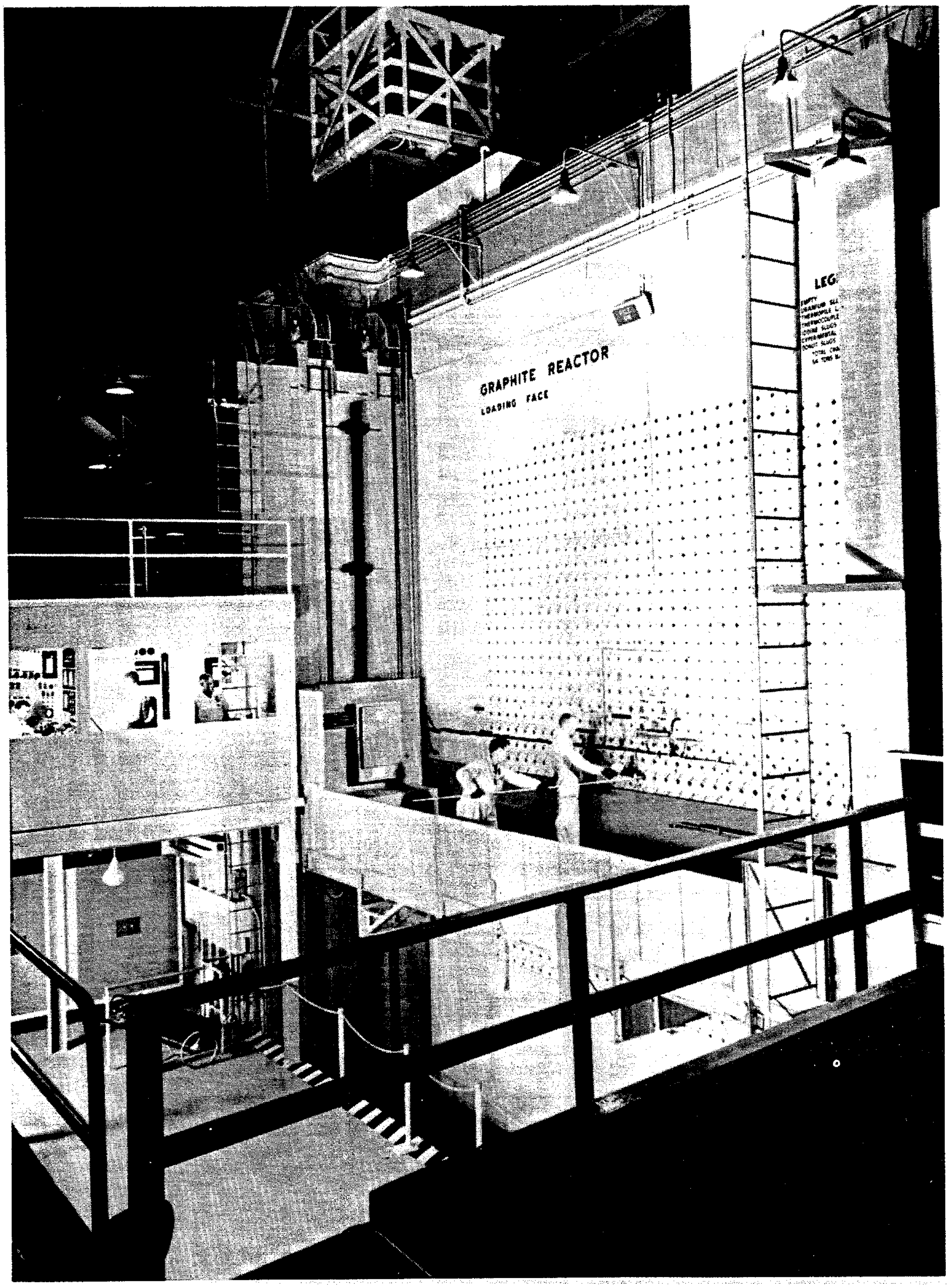
After its original mission was complete, the Graphite Reactor became a prime research tool and producer of radioactive isotopes. It produced the first electricity from nuclear energy, even though at a "toy" scale, and was the first reactor used to study the nature of matter and the health hazards of radioactivity. Later developments included energy sources for providing power for satellites, space equipment, and weather stations and for making radiographs. The radioisotopes proved to be valuable for use as tracers in agricultural, industrial, and medical applications. Although these radioisotopes are no longer produced at ORNL, the Graphite Reactor was instrumental in creating a worldwide reputation in radioisotope production. The Graphite Reactor existed during a time when radiation safety standards were first being developed and in some cases were nonexistent. The reactor was slow, cumbersome, and had no containment; thus, as more sophisticated and higher-flux tools for research were developed, the reactor became obsolete.

On September 13, 1966, the Oak Ridge Graphite Reactor was designated a Registered National Historic Landmark. Alvin M. Weinberg, then director of ORNL, The Graphite Reactor gave the Laboratory worldwide recognition, and on September 13 1966, it was designated a Registered National Historic Landmark.



paid tribute to the reactor when he said, "She shall always stand as a symbol of Oak Ridge and of the Oak Ridge National Laboratory. She is reincarnated countless times as she appears and reappears in the seal that symbolizes the Oak Ridge National Laboratory." This seal was replaced by a more modem stylized ORNL logo in the 1980s.

On February 18, 1992, the American Nuclear Society voted to recognize the Graphite Reactor as a "nuclear historic landmark," joining a number of sites around the country noted by the society for significant contributions to the growth of the nuclear industry. The reactor is also a prime attraction at ORNL's 50th year celebration.

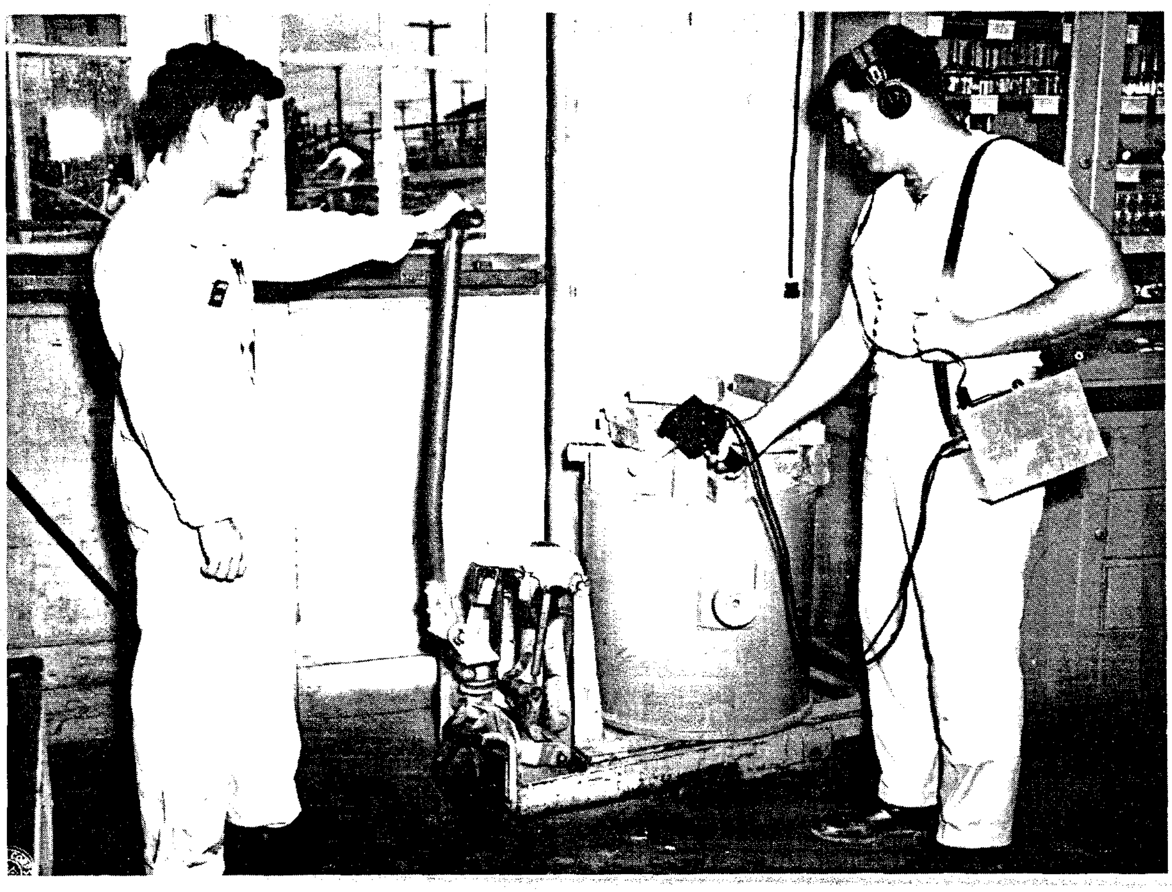


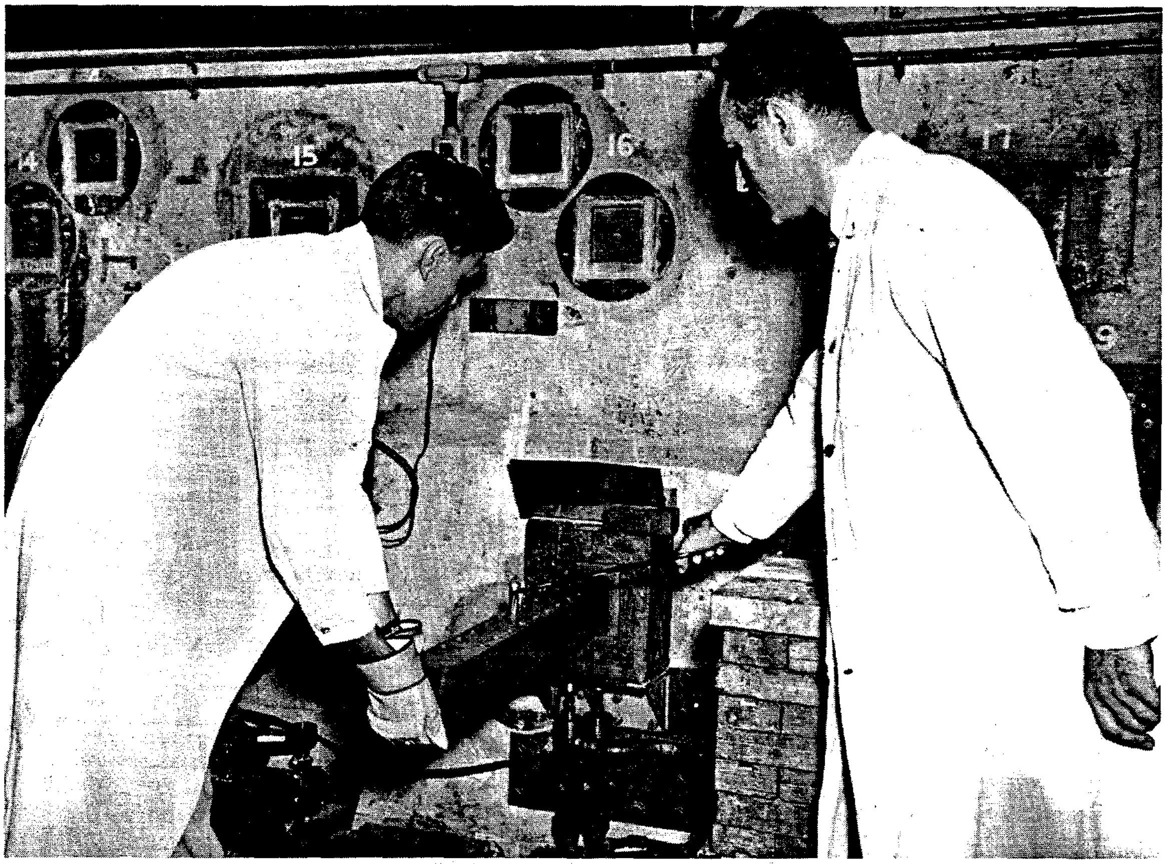
The Oak Ridge Graphite Reactor and control room.

Radiation

Operators at the Graphite Reactor had an unusual system for changing the "mattress plates" at the back of the reactor. Neoprene-coated wooden slabs collected slugs before they were sent to a deep pit under the water. When the plates got worn and beaten and slugs got hung up on them, the operators would take them out and change them. A "hot" truck was sent to the site, and the plates were pulled out and put in the trucks as quickly as possible. Prior clearance was obtained at the gate and, with radiation monitors blaring, the truck driver would drive out the gate as fast as he could without stopping until reaching the nearest burial ground and dumping the plates.

Transporting "hot" uranium from the Graphite Reactor to a "hot lab" for radioisotope production. The uranium is being monitored as it is transported in a heavy lead "pig." Notice the bricks stacked on top of the "pig."





Dr. Waldo Cohn demonstrates how samples of materials are inserted into the pile to make them radioactive.

National Geographic Account of Graphite Reactor

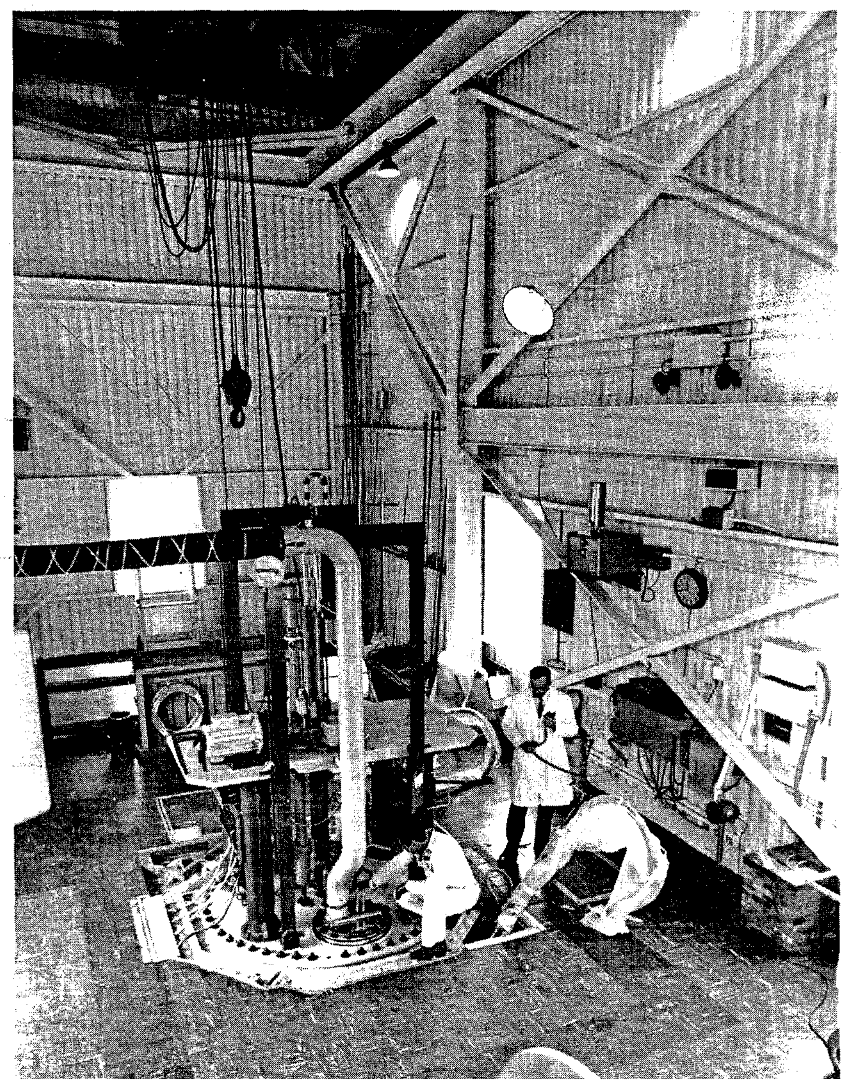
F. Barrows Colton, assistant editor for a 1954 ***National Geographic*** magazine, toured ORNL and the Graphite Reactor and published an interesting article about his visit. The article describes the reactor as a servant of man helping to build a better world. The following is Colton's first impression of the reactor. "As I walked through a door into the tall hangarlike building which houses the Oak Ridge reactor, I saw looming high above me a cube of pastel-green concrete as tall as a three-story house. No sound came from behind the fortress-like walls, no smoke emerged, and no wheels turned; yet I could sense somehow the presence of mysterious forces, unheard and unseen."

Low-Intensity Test Reactor

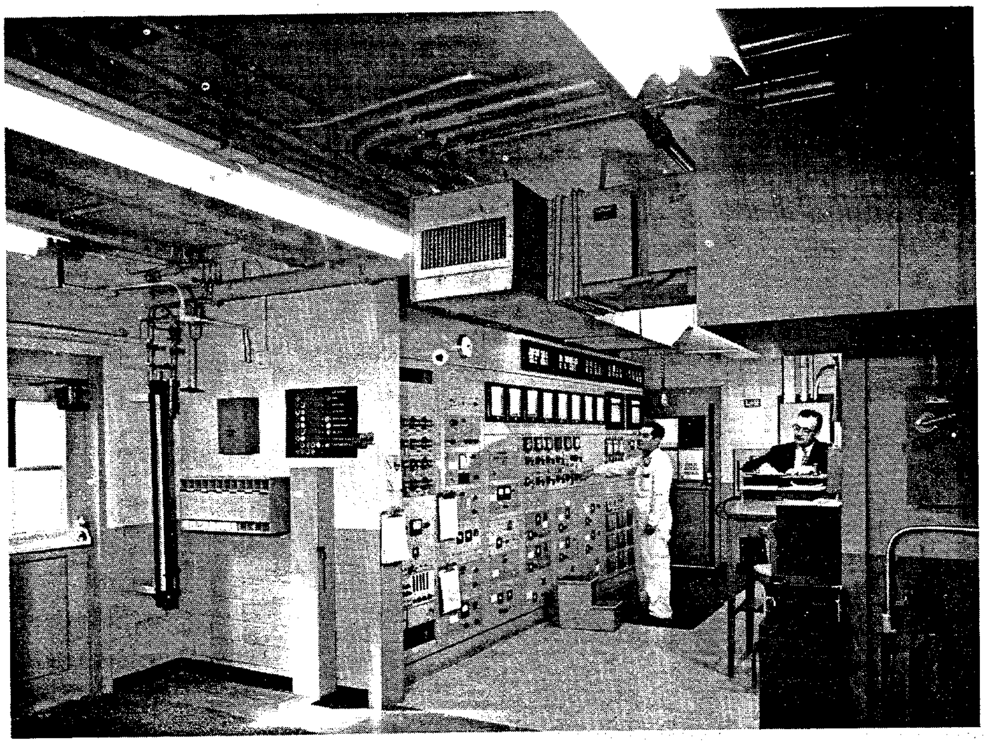
The LITR was originally built as a hydraulic and mechanical mockup for the Materials Testing Reactor (MTR), which was designed at ORNL and built in Idaho. The LITR was not built to operate as a reactor. However, following the planned tests, the core region was judged to be close enough to the final design to be brought to criticality for nuclear measurements such as gamma-ray heat deposition and checkout of instrumentation and controls. The LITR was also used as a training facility for Phillips Petroleum Company personnel to learn how to operate the MTR in Idaho. Later, ORNL and the AEC agreed that the LITR could be useful as an operating reactor and, after a number of modifications and power level increases, the LITR was brought to critical operation at a power level of 3 MW. Operation continued until the reactor was permanently shut down on October 10, 1968.

As part of ORNL's responsibility in the design of the MTR, critical experiments were conducted at the LITR on various MTR core configurations to verify the nuclear calculations. Marvin Mann of the Physics Division was responsible for conducting these experiments, the results of which Mann reported directly to Alvin Weinberg. These critical experiments were conducted in cells 6 and 7 of Building 3019. One experiment of note was the boiling of the LITR to observe the effects on controls and instrumentation and overall reactor behavior. This experiment, designed by Tom Cole and Jim Cox, was one of the steps that later led to the General Electric Boiling Water Reactors.

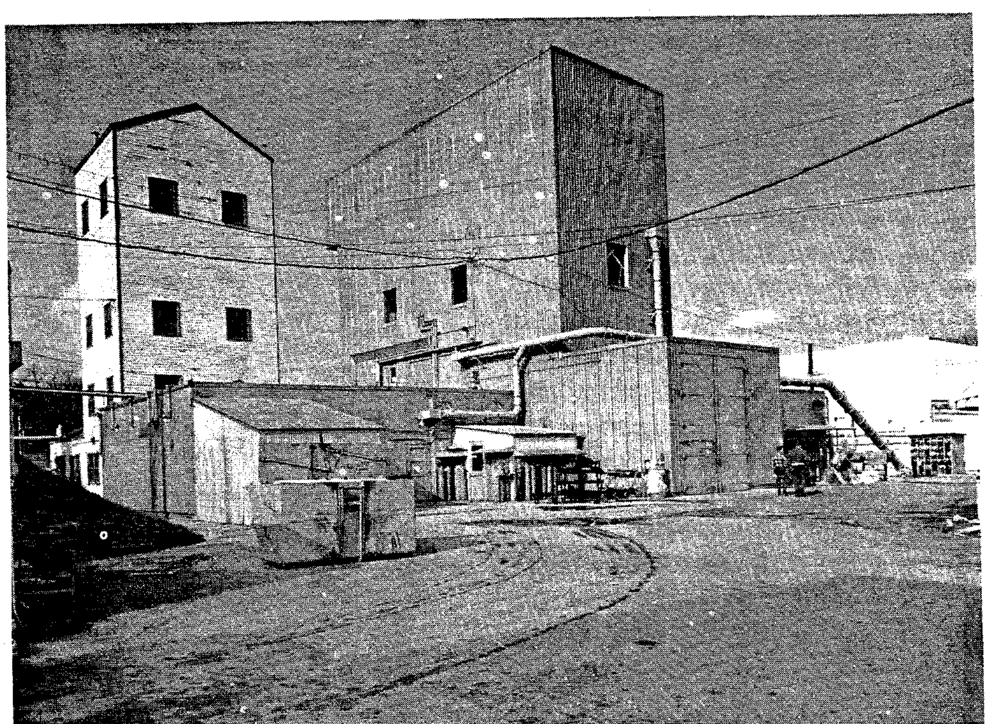
According to Reuben McCord, a former experimenter assisting in conducting the critical experiments, procedures for experiments were quite different in the late 1940s and 1950s from the way they are today. For example, a very isolated goup



The Low-Intensity Test Reactor



The LITR control room.



The center building housed the LITR and was the site of many critical experiments in the 1940% 1950s, and 1960s.

worked on the MTR experiments. This group would decide each morning what kind of experiment they wanted to run and with Mann's concurrence would proceed with the work. There were no written procedures to follow and no prior approval from upper management or the AEC.

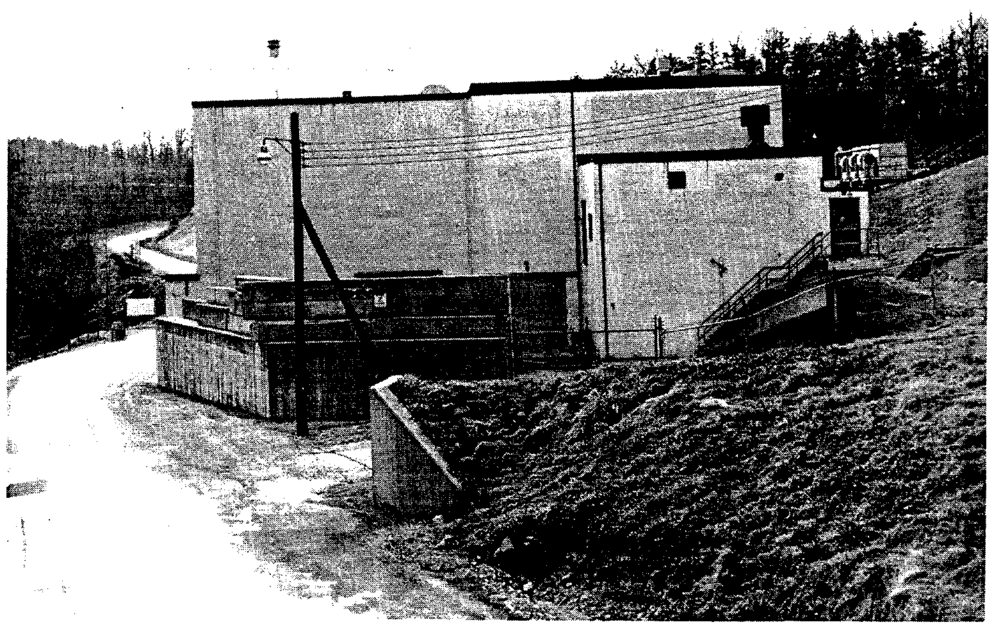
The LITR was operated in the same era as the Graphite Reactor, ORR, and BSR. Originally, each reactor had its own control room and control room operator. However, later, as an economic measure, the control rooms were consolidated. Thus, these reactors were unique in that more than one reactor was operated from the same control room. When the Graphite Reactor was eventually shut down, some of the LITR controls were moved to the ORR control room. In 1968, when the LITR was shut down, controls for the BSR were moved to the ORR control room. Gary Coleman, supervisor of the ORR and BSR, says that this type of operation permitted one operator to efficiently monitor two operating reactors simultaneously after they had reached equilibrium Rower level.

This type of reactor is well known for the blue glow, called Cerenkov radiation, emitted from the reactor pool. The LITR is famous for being the first reactor to have its blue glow photographed.

Critical Experiments Facility

ORNL's Critical Experiments Facility **(CEF)** was constructed expressly to meet the needs of various programs of criticality experiments. Prior to its construction several critical experiment programs had been carried out at ORNL and the Oak Ridge Gaseous Diffusion Plant. These experiments included an extended program to support the design of the Materials Testing Reactor. The inadequacy of the facilities at these two locations was recognized in 1949 in light of expected demands for further experimentation in both the investigation of the safety of metallurgical and chemical processes and the support of reactor designs. This latter need was further emphasized by a then-active program on the development of nuclear propulsion for aircraft. At that time it was decided that a laboratory adequate for this type of experimentation would be established, that the various programs of critical experiments in Oak Ridge would be combined, and that the work would be administered by ORNL. The new laboratory was occupied on August 1, 1950, and has been the scene of an extremely wide variety of critical and near-critical experiments with fissile uranium isotopes. The CEF has been used in experiments with liquid fuels, in designing the TSR-II core, and in testing and criticality experiments for the first HFIR fuel. Experiments were also done to determine the effects of airborne radiation resulting from an accident.

The CEF is located at a remote site in the southwest portion of the Y-12 Plant site. It is situated in a pocket in the terrain formed by surrounding hills several hundred feet higher than the building itself. The facility is a two-story concrete and concrete block structure about 200 ft long and 80 ft wide. It contains three assembly areas or test cells and a control room. During operation, visual



This building housed the CEF located at the Y-12 Plant site. The CEF operated from 1950 to 1987.

communication between the control and test areas was provided by water-filled windows; verbal communication was by intercom. Several other features were incorporated in the design of the CEF to improve personnel protection. In some places, for example, windows were substituted for solid walls where the latter could have backscattered radiation into normally occupied areas.

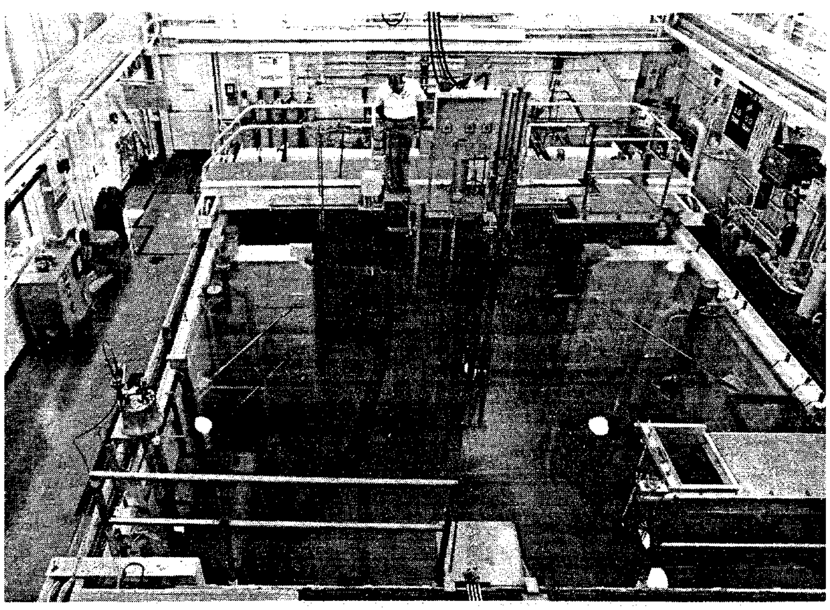
The CEF was organized as a part of the Neutron Physics Division of ORNL. The responsible division established a Reactor Safety Review Committee that annually reviewed each experimental activity within the division. The committee consisted of the division director, the supervisors of the various facilities operated within the division, and other experienced technical personnel. The operations within the facility were reviewed by the Laboratory's Reactor Operations Review Committee (RORC).

The CEF was staffed by a number of technically qualified individuals. In 1962 the facility technical staff comprised ten scientists, three technicans, and a part-time health physicist. The CEF was used from the 1960s through March 1987 for performing reactivity measurements of each of the HFIR fuel assemblies. Operations Division and Research Reactors Division personnel who were senior reactor operators at the CEF include Tom Hamrick, Randy Hobbs, Frank Kam, Mark Kohring, Marshall Sims, Regina Stinnett, and Jerry Swanks.

The facility is currently in shutdown mode and is awaiting permanent shutdown orders. An alternative method for verification of the shutdown margin for HFIR fuel assemblies was developed by Research Reactors Division staff and approved for use in 1992. Therefore, a restart of the CEF is not necessary.

Bulk Shielding Reactor/Pool Critical Assembly

The Bulk Shielding Reactor was originally a 10-kW reactor, housed in the Bulk Shielding Facility (BSF), that operated from 195 1 to 1963 as a source for radiation-shielding experiments. The reactor was and is known as the "Swimming Pool" reactor and served as the model for scores of university, industry, and government facility reactors. The initial programmatic goal for the reactor's lifetime was 10 years. Because of a change in emphasis in the national neutron physics program and the shutdown of the Graphite Reactor, the BSR's lifetime was extended and it was made available for use as a general-purpose research reactor in 1963. It operated in this capacity until DOE ordered all ORNL research reactors shut down in March 1987. The BSR received permanent shutdown orders on September 10, 1991, having never restarted following the shutdown. The Geneva Conference Reactor was also tested in the BSF pool. Several Operations Division personnel participated in the operation of that facility in Geneva, Switzerland.



The BSR is known as a "'swimming pool" type reactor.

The BSR was considered a low-cost reactor, and exact costs as of the summer of 1950 determined from ORNL records show this to be true. Fuel elements cost approximately $120 each (not including enriched uranium costs), the reactor assembly cost $28,000, and the electronic circuits were $30,600. Thus, with 20 fuel elements, the reactor and-controls **totalled** $5 1,000. A beryllium reflector, spare parts, and health physics instruments **totalled** $33,500; and the building and pool cost approximately $125,000, making the total cost of the original BSR a little more than **$200,000**, an astonishingly small cost for a research tool of this nature! This is less than the cost of many homes in Oak Ridge today.

Several changes were made to the BSR when it became a general-purpose reactor. The facility was provided with a **forced-**cooling system and was upgraded to permit **continous** reactor operations at a thermal power level of 2 MW. The reactor used **aluminium-clad** uranium-aluminum alloy fuel elements while water cooled the fuel core, moderated the neutrons, and also, either alone or with other materials, reflected neutrons back into the core to help sustain the fission reaction. Experiments at the BSR included studies of radiation-induced defects and the effects of radiation on material properties.

In addition to the BSR, the BSF also houses the Pool Critical Assembly (PCA) in the same pool. The PCA, located near the northwest comer of the pool, was a versatile research tool intended to augment the BSR, the LITR, and the ORR programs by handling most of the low-power (up to 10 **kW)** experiments for these reactors. For example, it was used for trainees, for field testing proposed modifications in control instrumentation, and for various experiments.

The philosophy of operation for the PCA evolved from a number of years of experience with the BSR and from experience with the PCA itself. The instrumentation for the PCA is quite similar to that of the BSR. As part of its training capabilities, the **PCA's** control room operator was responsible for both the mechanical actions of the control system and for evaluating various conditions indicated by the control instrumentation. Because of its hands-on capability, the PCA helped train nuclear engineering students from major colleges and universities all across the United States. These students used the PCA for many hands-on experiments to augment their classroom instruction, and ORNL and Tennessee Valley Authority personnel used the PCA to train reactor operators. Thus, the PCA has been a useful learning tool for many technical personnel.

In addition to its training capabilities, the PCA was also used for low-power experiments. Each in-reactor experiment was subjected to comprehensive reviews and hazards evaluations by the Laboratory's Reactor Experiment Review Committee and by the Operations Division. In this way, an experiment was approved for operation within safety limits applicable only to that specific experiment.

The PCA was shut down in 1987 with DOE's order to shut down all ORNL research reactors. According to Roger Stover, current Category B Reactors Section manager, there is an ongoing effort to upgrade the PCA and bring it back as a training tool.

The BSR Pool

The BSR is known as a swimming pool type reactor especially to Charlie Gather who literally used it as a swimming pool. Gather was standing by the pool on a catwalk when Jim Cox, then Reactor Operations Section manager, walked into the building. Cox yelled something to Gather, and Gather turned quickly to answer him. As he turned, Gather lost his balance and, rather than land on the concrete below, decided it was safer to just jump in the BSR pool.

Oak Ridge Research Reactor

The ORR was designed and developed from the need for a reactor with a high neutron flux for basic research in the fields of physics and chemistry and to test materials and potential fuels for power-producing reactors. The existing Graphite Reactor had only a very low neutron flux, and the demand for isotope production was growing to a level greater than the Graphite Reactor could supply. Oak Ridge needed a high-flux reactor similar to the MTR in Idaho. In 195 1, preliminary studies for a new reactor began and resulted in the Atomic Energy Commission's (AEC's) authorizing construction of the ORR. The design of the reactor and its facilities was influenced by two important requirements. First, the reactor had to be capable of accepting different types of experiments with minimum interference to routine operation. Second, significant radioactive contamination of the environment from any cause whatsoever must be prevented. The former was necessary for the reactor to fulfill its mission as a research tool. The latter was, of course, required of any reactor built and operated at ORNL.

Construction began at the X- 10 site in the summer of 1955, and the reactor was completed near the end of 1957 at a cost of $4.7 million, Criticality was reached in March 1958, and the AEC authorized routine operation at power levels up to 30 MW two months later. The reactor was operated at a power level of 20 MW until mid- 1960 when a new cooling system was installed and the power was raised to 30 MW.

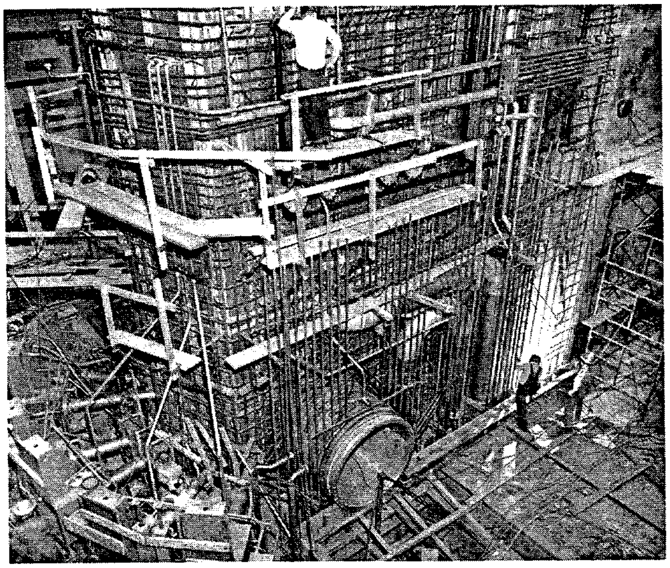
The ORR was a light-water-moderated and-cooled, beryllium- and water-reflected research reactor designed and built for use as a general-purpose research tool. It employed highly enriched uranium-aluminum alloy plate-type fuel similar to that of the MTR, the original reactor of this general type. Operations personnel, under the direction of the ORR Project Group, were trained on the various systems of the reactor. Many changes were made during the years of operation to facilitate remote fuel and experiment handling and to improve the water cleanup systems.

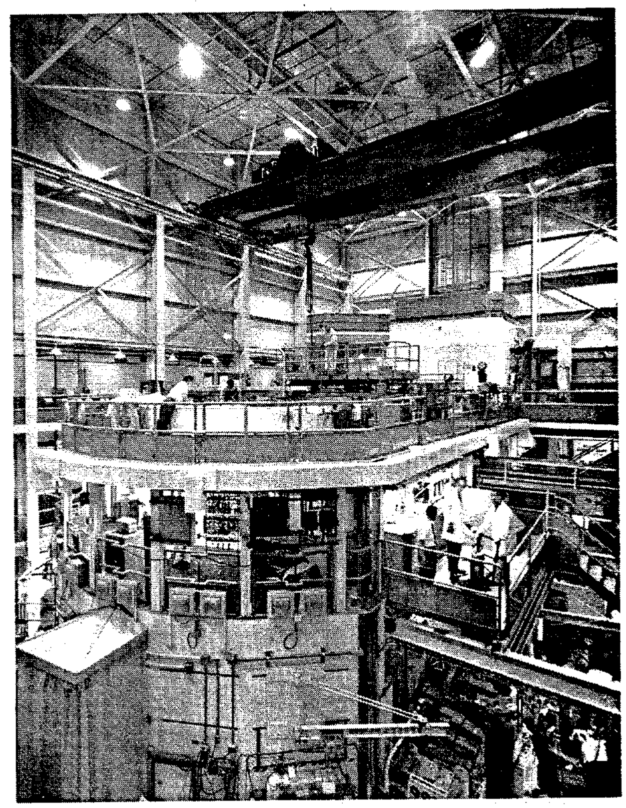
As a result of the design specifications, the ORR's unique research and production features allowed it to produce the isotopes needed for research, medicine, and industry faster, more economically, and in greater quantities than any other reactor anywhere at that time. The ORR also contained the most advanced safety features, which included filters and a scrubber system to clean old air leaving the facility and protect the outside population in the event of a release from an experiment or the reactor. These features also allowed for increasing the power level to greater than 30 MW. Design concepts of the reactor, such as locating the reactor near one end of a pool, have been used in other reactors in Sweden, South Africa, The Netherlands, and France. Many of these reactors are still in use.

During the latter part of 1957 and the early part of 1958, various neutron and hydraulic tests were performed that permitted an evaluation of the effects of experiments on water flow, neutron distribution, and reactivity. As a result, many changes and modifications were made to improve the operation and reliability of the ORR.

The ORR was also the scene of many new experiments in the fields of nuclear and solid-state physics. The reactor was used for many studies on the properties of metals, alloys, ceramics, and nuclear fuels as well as

1956–The reactor and storage pool take shape. The neutron beam ports are in the left foreground, and the cooling water outlet is at the bottom right.

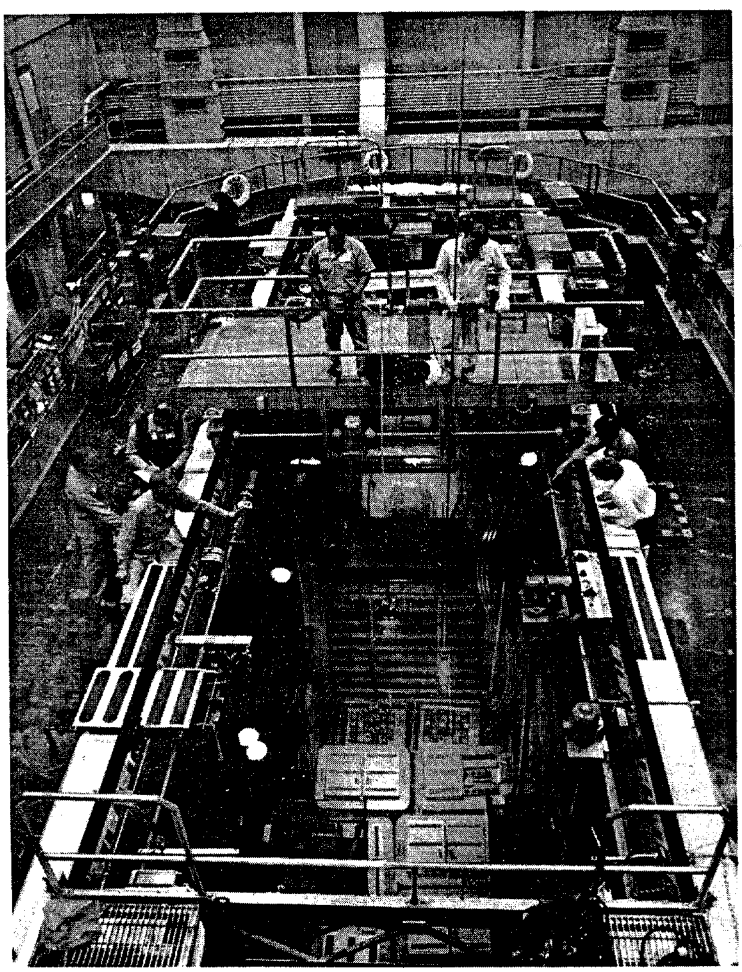




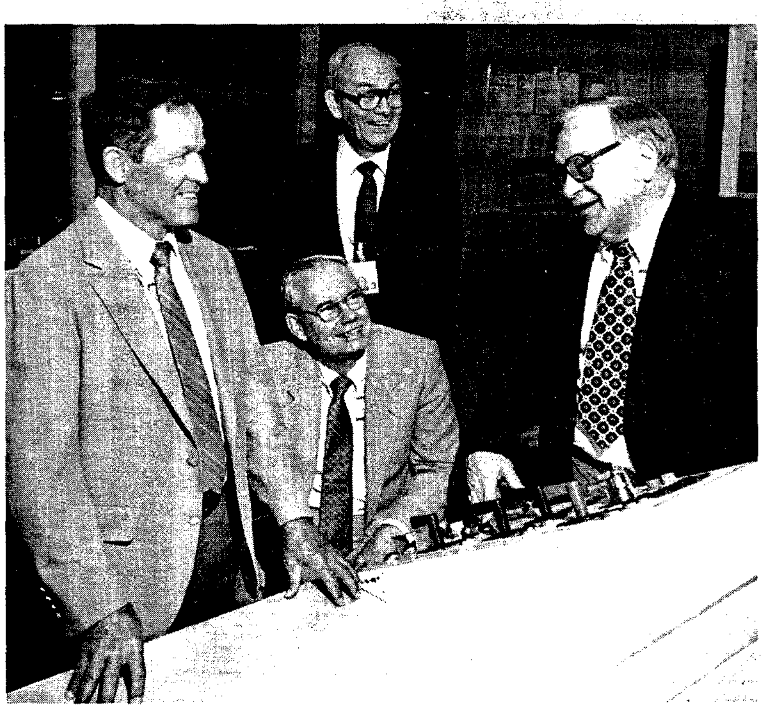
The ORR with its four working levels for research and isotope production was completed near the end of 1957. Criticality was reached in March 1958.

for neutron-scattering research, neutron spectrometry, and fundamental engineering studies of the effects of radiation on materials. Fuel studies were also performed for a proposed nuclear-powered surface ship.

During its many years of successful operation, the ORR became famous in many different ways. The Analytical Chemistry Division used the ORR for highly sensitive crime studies for the Federal Bureau of Investigation. In addition, the reactor held the unique status of being the primary supplier of radioisotopes to the free world. Perhaps the most famous characteristic of the ORR was its blue glow, known as Cerenkov radiation. Royalty and presidents visited the facility to see this blue glow while famous scientists and engineers competed to use the reactor for experiments.



The **ORR's** famous blue glow, known as Cerenkov radiation, brought visiting dignitaries from around the world.



October 5, 1985—The ORR's 10,000th day of operation. ORR supervisors (from left) Sam Hurt (1973 to 1982), Bernie Corbett (1982 to 1985), Bill Tabor (1958 to 1973), and Tom Hamrick (1985 to 1987 shutdown) gathered for the occasion.

The ORR operated safely for 29 years with no serious difficulties or interruptions until the new and improved irradiation and neutron-scattering facilities at the HFIR became available. It is interesting to note that a partial melt of one of the fuel plates caused only a few days' minor disruption in operation.

DOE ordered the ORR shut down in March 1987 along with the rest of ORNL's reactors. The ORR is currently in shutdown status. RRD will transfer the facility to the Office of Waste Management and Remedial Action in September 1992 where it will then await approval for decontamination and decommissioning.

ORR Experimenter

Rodney Knight, longtime ORNL employee and currently in charge of RRD's fuel procurement, developed the first two experiments to go into the Oak Ridge Research Reactor. The first experiment, called C 1 ,was a leak test experiment. The second experiment, B9, was developed so that it could be pulled out if it became too irradiated or "hot." Knight's B9 experiment design has been used all over the world.

The Famous Blue Glow

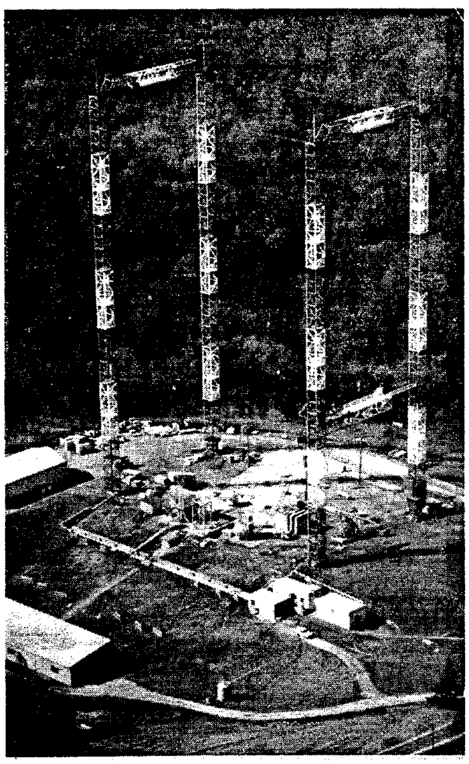
The Oak Ridge Research Reactor's blue glow of Cerenkov radiation made it a mandatory stop for many visiting dignitaries. Some of the most famous visitors to the ORR were President and Mrs. John F. Kennedy, King Hussein of Jordan, and Queen Fredricka of Greece. Current Research Reactors Division employees Gary Coleman and Sam Hurt III were involved in many of the dignitaries' visits. The Kennedys came to visit

In this historical photo, ORNL Research Director Alvin Weinberg (center) and Sam Hurt (far left), assistant ORR shift supervisor, are shown giving a tour of the reactor for Senator John F. Kennedy , Senator Albert Gore Sr., and Jacqueline Kennedy on February 24, 1959.

the ORR before the former entered the race for president. Alvin Weinberg, then ORNL director, recounts a humorous story about that visit: I remember asking ORNL's deputy director John Swartout to take Jack Kennedy and Senator Albert Gore, Sr., around the ORR while I, exercising my prerogative as director of the Laboratory, showed Jackie around."

Tower Shielding Facility

The Tower Shielding Facility (TSF), which has been an integral part of Oak Ridge National Laboratory's reactor program for almost 40 years, is the only known facility in the world capable of doing large-scale radiation transport studies needed for the advancement of computer and nuclear data for shielding analysis. The facility was designed and built for the Aircraft Nuclear Propulsion (ANP) Project in 1954 to provide a source that would permit measurements free of radiation scattering from the ground or any enclosed structure and that would permit reliable comparisons with analytical predictions of radiation distribution. To provide this environment, four steel towers were constructed in a rectangular array on top of a knoll near the Clinch River so that the reactor, shield, and instrumentation could be raised up to 200 ft above ground level. This permitted measurements to be made'in the air with minimal reflection of radiation from the surrounding terrain. Although the ANP Project has long since been terminated, the versatility and usefulness of the TSF continues to make it a valuable tool in shielding research.



The facility consists of four 315-ft-high towers erected on the comers of a 100- by 200-ft concrete pad. Two of the towers were originally used for suspending the reactor; the other two towers, as well as the bridges connecting both pairs of towers, can be used to support other equipment, such as secondary shields and detectors. A reinforced concrete handling pool provided the shielding needed during shield changing and reactor servicing. The operating crew near the tower array, the control room, and a maintenance shop are housed in underground earth-shielded rooms.

The TSF has been an integral part of ORNL's reactor program for almost 40 years.

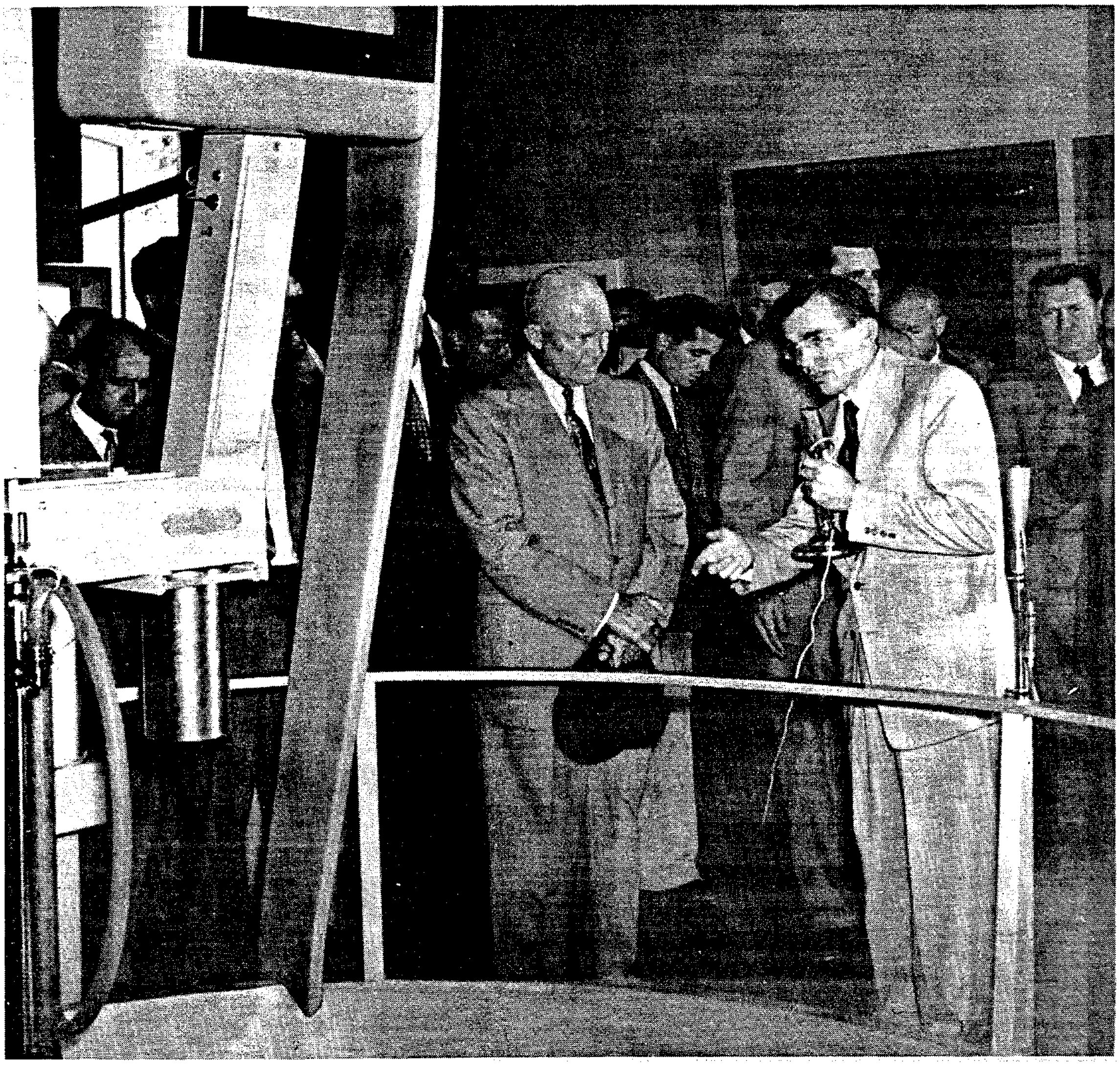
The TSF has housed four different reactors since it was first built, three of which were operated while suspended from the towers. The original Tower Shielding Reactor (TSR-I) was a box-shaped 500-kW MTR-type reactor. For a brief period beginning in 1958, the Aircraft Shield Test Reactor (ASTR), used for shielding research in an operating aircraft, replaced the TSR-I. The TSR-I was replaced in 1960 with the spherically symmetric **TSR-**II, which is still in use. The TSR-II can be operated at 1 MW and more closely simulates the idealized spherical reactor used as a basis for machine calculations. In 1967, the **TSF-**SNAP (Systems for Nuclear Auxilary Power) reactor was added to be used alternately with the TSR-II for shielding studies but with an independent suspension system. The **TSF-**SNAP reactor was removed from the TSF in 1973. Since 1975, the TSR-II has been located in a ground-based concrete shield (Big Beam Shield). From 1975 to 1987 the TSF was also used to test the integrity of shipping casks for hazardous materials by dropping casks suspended from two of the towers from a height of 9 m (30 ft) and 1 m (3 ft) onto an armor plate imbedded in the top of a massive, reinforced concrete pyramid.

The TSR-II instrumentation system was first used to operate the reactor at the TSF on March 30, 1960. After several months of critical experiments, the reactor was disassembled for modifications. After reassembly, the reactor was first operated with full cooling-water flow on December 22, 1960. On February **6, 1961,** it was operated at a maximum authorized power of 100 **kW.** The maximum authorized power was raised in 1972 to 1 MW, and the reactor has been operated at various powers up to 1 MW since that time. In addition to the allowed l-MW maximum power, the TSR-II has a uniquely designed core and control configuration. The core comprises many aluminum fuel plates formed into a spherical **annulus** surrounding a spherical control mechanism housing. The simple geometry of the core and the central placement of the control material allows for very accurate analytical predictions of the reactor's source characteristics.

Personnel access control at the TSF is a key element in protecting personnel from radiation. All personnel entering the TSF area are issued a tally or muster badge. Prior to operation, the individual operating the reactor, in accordance with procedures in the TSF Operating Manual, checks that all personnel are in a safe location, accounted for, and informed of the restrictions in force during the operation.-Before operation can be initiated, a warning horn blows for three minutes to alert any personnel who may have been missed in the personnel check that operation is imminent. To ensure that personnel cannot inadvertently approach the reactor area during operation, interlocks will cause a reactor shutdown if anyone opens a door to leave the control building or opens a gate in the **600-ft-radius** fence to enter the area.

The TSF staff has been reduced considerably from its original staff of about 20 technical, craft, and theoretical contributors to a staff of 7. However, as Leo Holland, TSF manager with over 40 years experience with the shielding program, attests, all those who have been or are now involved with the program have played a key role in the development of shielding for all types of reactors. Holland states, "The efforts of the theoretical and experimental staff have saved millions of dollars by providing proven shield configurations for the initial design of power reactors, which avoided the need for later retrofitting." This experience and a diverse collection of well-tested **radiation-**detection systems are also factors that have contributed to the overall importance of the facility.

The TSR-II has been used for a variety of experiments, both at ground level and at elevated positions. It has been used to provide information for the design of shields for space systems and defense applications and has been relied upon by other reactors, including commerical reactors, for data and experiments. The facility's 1 MW of power and unique spherical shape produce more



President Eisenhower, visiting the "Atoms for Peace" exhibit in Geneva, Switzerland, listens to an explanation of the U.S. Exhibit Reactor by Leo B. Holland.

usable radiation that will penetrate a larger shield and provide data more quickly than other reactors. The TSR-II is also unique in that it is the only reactor of its size in the world today dedicated to conducting nuclear shielding experiments, This uniqueness of design and capability of the TSR-II has resulted in a very successful cooperative program with the Japanese government. The reactor is a valuable tool in validating shielding designs for the Japanese-American Shielding Program for Experimental Research (JASPER). JASPER is a program to assess shielding designs for reactors in both the United States and Japan. Funding of this research is provided by the Japanese government and the U.S. Department of Energy. Leo Holland says, "It's really gratifying that the Japanese recognize our depth of experience and have placed such high value on staying with us through some of the hard times." The JASPER program will be completed in late 1992, however, and DOE maintains that if no follow-on program is standing ready when the program is over, the TSR-II should be permanently shut down. The Laboratory believes that the TSR-II will be needed for a number of near-term, important programs, including the Advanced Neutron Source project, and should be placed on standby status until those programs mature to the point where testing of shielding designs is required.

The TSR-II was shut down in 1987 along with ORNL's other research reactors but was restarted in December 1989. The reactor was shut down again in March 1990 for replacement of a major component but was restarted in early July 1990 and remains a vital national resource in reactor shielding technology. According to Director of Reactor Operations Jack Richard, "The TSR-II is unique in the world for shielding design verification, and it should be retained."

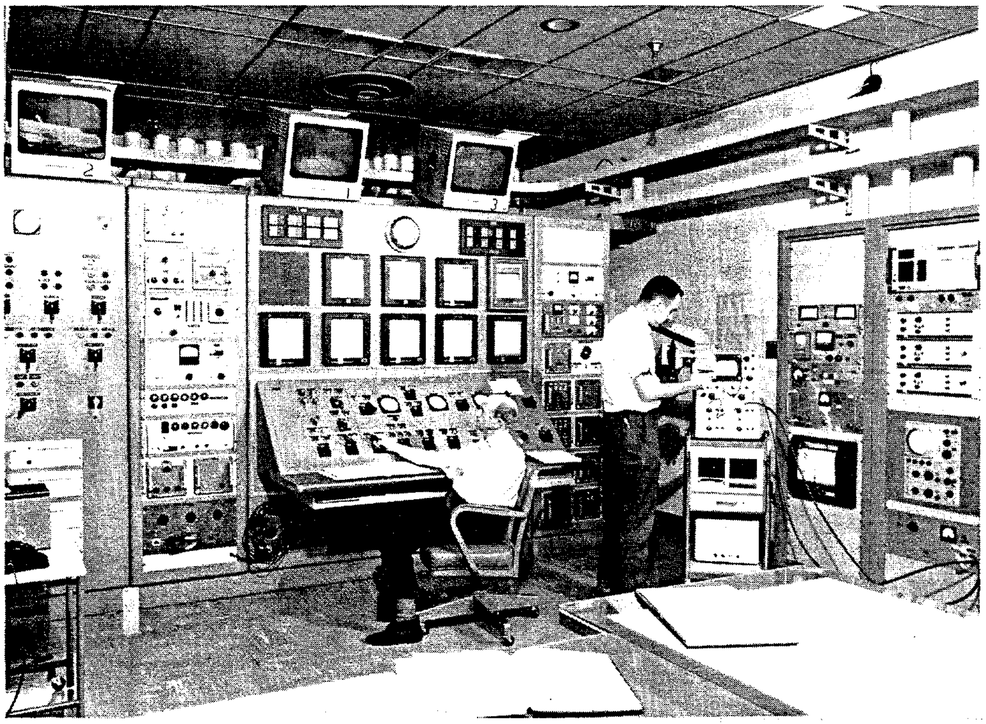
Health Physics Research Reactor

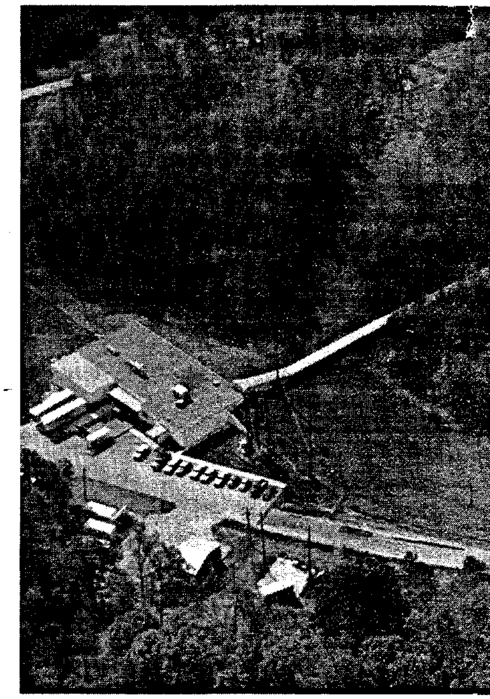
The Health Physics Research Reactor (HPRR), also known as the Fast Burst Reactor, was designed and constructed at ORNL. Following initial testing it was loaned to Operation BREN (Bare Reactor Experiment Nevada) at the Nevada Test Site (NTS) near Las Vegas. This experiment provided data to the United States Army that aided in the evaluation of radiation doses to the populations of Hiroshima and Nagasaki that resulted from the nuclear bombings in 1945. To simulate nuclear weapon effects, the reactor was operated at various elevations on a hoist platform on a 1500-ft tower at the NTS. After only a few months operation at the Nevada site, the HPRR was moved to the DOSAR (Dosimetry Applications Research) Facility two miles southeast of the main ORNL complex where it was deployed for health physics and dosimetry applications.

The HPRR was similar in principle and construction to the Los Alamos Godiva II reactor and was the primary research tool at the DOSAR Facility. The-reactor was a small, unshielded, unmoderated, fast reactor designed to fill the need for a neutron irradiation facility for health physics and biomedical research. The facility was set up to ensure maximum efficiency of operation and protection of personnel. It consisted of a reactor building that housed the HPRR, a control building, and auxiliary buildings. The reactor was housed in an aluminum building and was supported by a large track-mounted positioning device called a transporter. Aluminum was used for the building structural material because it combined strength with a low-scattering cross section for radiation from the reactor. The transporter allowed the HPRR to be positioned to within 1 cm of any preselected point along the centerline of the track and up to a height of 5 m above the 30-cm-thick concrete floor. When not in use the reactor was stored in a steel and concrete vault below floor level.

The control building is still located behind a hill 900 ft from the reactor building and contains the HPRR control room, offices, experiment laboratories, a counting room, and a machine shop. The auxilary buildings housed neutron and gamma-ray calibration facilities and provided storage space. Perhaps the most remarkable fact about the HPRR is that this extensive setup was designed and developed for such a powerful but small piece of equipment. The reactor core is only about 8 inches in diameter by 9 inches high.

Initial checks for the HPRR were at the CEF in 196 1, initial operation was at the NTS in 1962; and initial operation at ORNL was at the DOSAR on May 3 1, 1963. The reactor has been operated 3000 times in the steady-state mode and 1000 times in the pulse mode. During steady-state reactor operation, the HPRR could be operated at power levels ranging from 0.1 W to 10 kW. At power levels under 100 W, the reactor could be operated for any length of time. The HPRR has an impressive operating history. Unscheduled shutdowns averaged less than three per year between 1970 and 1982. About 84% of the shutdowns occurred in the first half of the HPRR's operating history. As Steve Sims, formerly of the Health and Safety Research Division, which performed numerous experiments at the HPRR suggests,





The HPRR control room.

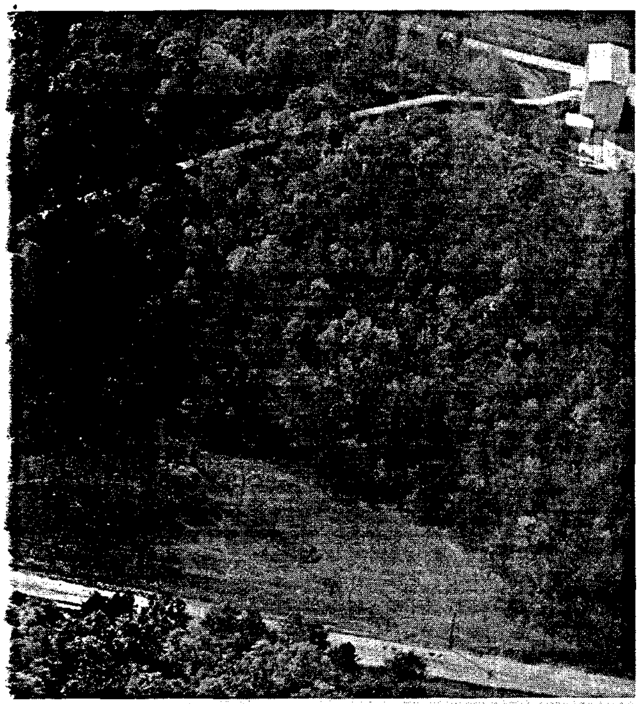
the HPRR has been maintained in excellent condition by operations personnel.

The **HPRR** was taken critical 6288 times without detectable harm to equipment or personnel during the first 20 years of operation. There were no occurrences in which the safety of any personnel was challenged or in which any failure seriously affected the equipment. After many years of successful operation, the HPRR was shut down in 1987 by DOE order along with the rest of **ORNL's** research reactors.

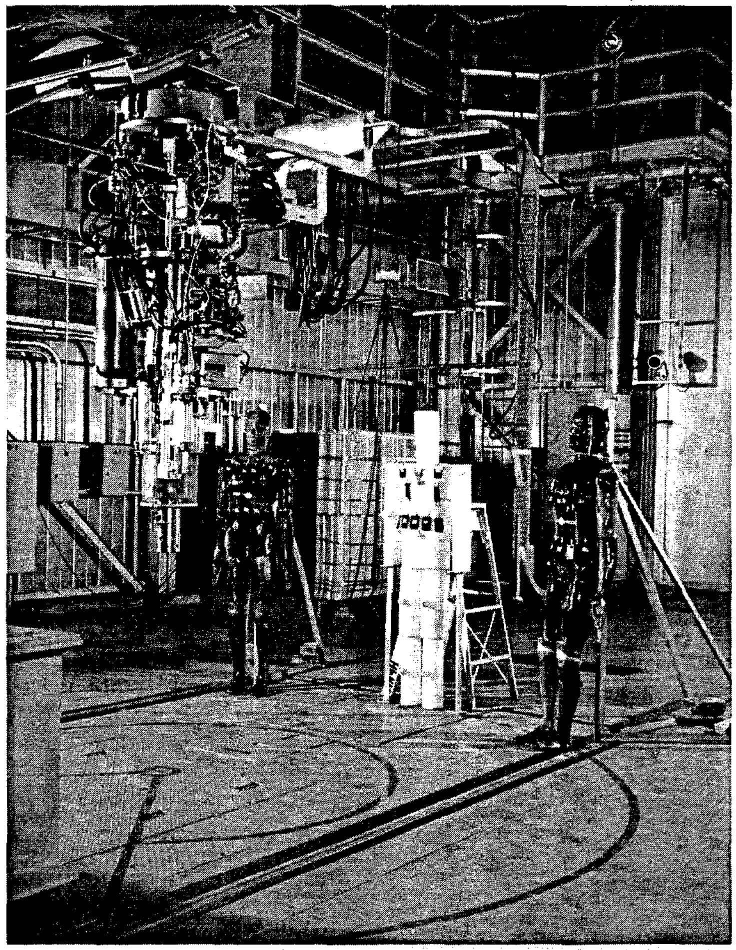
As mentioned, the reactor was used for a variety of purposes, including training in radiation dosimetry and nuclear engineering, radiobiology studies, dosimetry studies, weapon simulation, criticality alarm testing, and simulations of human-body radiation exposure experiments. The radiobiology studies determined the effects of radiation doses on animals and plants. Rhesus monkeys were irradiated at the HPRR to study radiation effects during space travel. Mice have also been studied in **cancer**-induction experiments. The results of dosimetry studies and human-body radiation simulations at the HPRR have helped set various guidelines for personnel dosimeters and radiation limits.

When the **HFIR** and TSR-II were restarted after shutdowns in the mid- **1980s,** ORNL proposed that the HPRR be the next reactor to be restarted. Restart activities were in progress in late 1990 when a safeguards and security concern arose, and DOE ordered the facility to be defueled and then directed ORNL to permanently shut down the facility. At that time, a substantial number of users had expressed interest in using the reactor.

The reactor itself has not yet been designated as surplus and is currently stored at the Y-12 facility. Director of Reactor Operations Jack Richard believes the HPRR should have a future in research. "The **HPRR,**



The HPRR facility. Operations at ORNL began on May 31. 1963. The facility is currently shut down.



Radiation dosimetry studies at the HPRR.

when it was shut down, was the best-calibrated and characterized facility of its kind in the world," he said. "The reactor ought to be retained as a national asset, either here or somewhere else."

Fugitive Hunt at TSF and HPRR

In October 1991 an armed fugitive was located in the area surrounding the TSF and HPRR. The TSF was shut down and both facilities were evacuated so that law enforcement agents could search for him. Personnel at the Laboratory were urged to remain in sheltered areas until the fugitive could be captured. The fugitive was later found on an island near the TSF and HPRR facilities on Melton Hill Lake.

High Flux Isotope Reactor

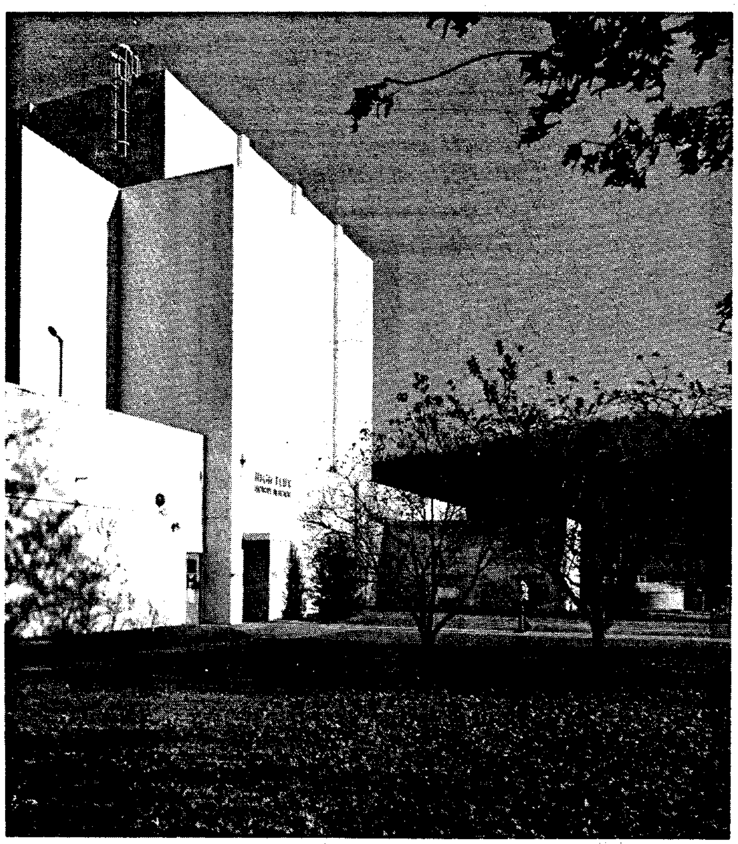
As the **ORR's** construction neared completion, toward the end of 1957, a series of informal seminars was initiated at ORNL to discuss the need for a next generation of high-flux reactors (ultrahigh-flux reactors) and to review the technical problems associated with such designs. The conclusions, published in mid- 1958, were that the most pressing need was for a very-high-neutron-flux facility for the production of transplutonium elements and isotopes and that a flux-trap type of reactor could best meet this need. This effort at ORNL fit in very well with the heavy-element production program of the AEC, and in the latter part of 1958 the AEC concluded that their program, which was using current reactors, should be accelerated. Following a meeting of the AEC and contractor personnel in Washington, D.C., cn November 24, 1958, the AEC concluded that a high-flux reactor of the type recommended by ORNL be designed, built, and operated at ORNL, with construction to start in FY 196 1.

As a result of this decision ORNL submitted a proposal to the AEC in March 1959. Authorization to proceed with the design of a high-flux reactor was received in July 1959, and in June 1961, preliminary construction activity was started at the site. In early 1965, with construction complete, final hydraulic and mechanical testing began. Criticality was achieved on August 25, 1965. The low-power testing program was completed in January 1966, and operation cycles at 20, 50, 75, 90, and 100 MW began. From the time it attained its design power of 100 MW in September 1966, a little over 5 years from the beginning of its construction, until it was temporarily shut down in late 1986, the High Flux Isotope Reactor (HFIR) achieved a record of operation time unsurpassed by any other reactor in the United States. By December 1973, it had completed its 100th fuel cycle, approximately 23 days each.

In November 1986 tests on irradiation surveillance specimens indicated that the reactor vessel was being embrittled by neutron irradiation at a rate faster than predicted. The HFIR was shut down to allow for extensive reviews and evaluation of the operation of this facility. Two years and five months later, after thorough reevaluation, modifications to extend the life of the plant while protecting the integrity of the pressure vessel, and upgrades to management practices, the reactor was restarted. Coincident with physical and procedun! improvements were renewed training, safety analysis, and quality assurance activities. Documents were updated, and new ones were generated where necessary. Technical specifications were amended and reformatted to keep abreast of the design changes as they were accepted by DOE.

After a thorough review of ***many*** aspects of HFIR operation, the reactor was restarted for fuel cycle 288 on April 18, 1989, to operate initially at very low power levels (8.5 MW) until all operating crews were fully trained and it was possible to operate continuously at higher power. Following the April 1989 restart, a further shutdown of 9 months occurred because of a question as to procedural adequacy. During this period, oversight of the HFIR was transferred to the DOE Office of Nuclear Energy (NE); previously, oversight was through the DOE

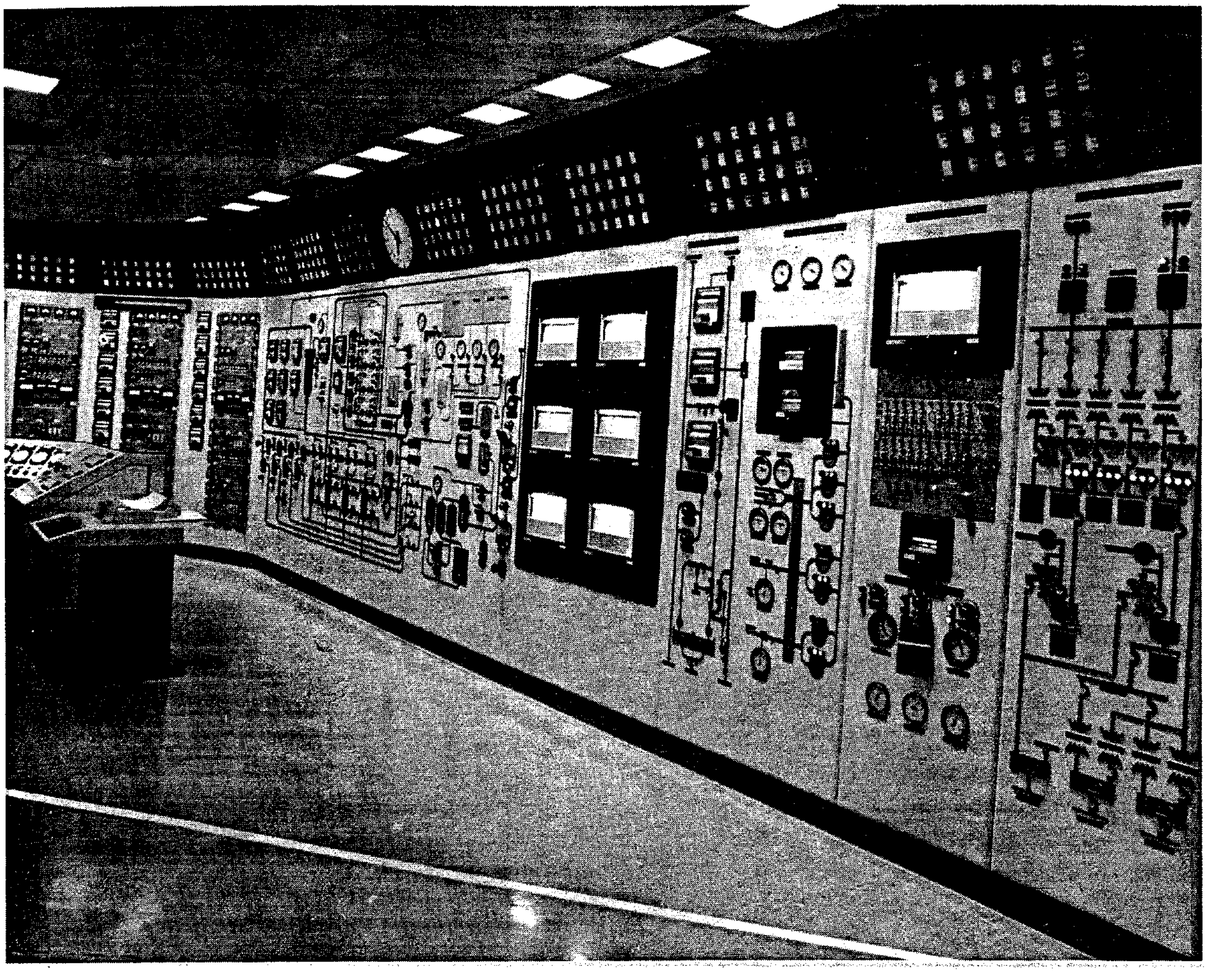
The operational chain of **HFIR operation.**



The **HFIR** building, which houses the reactor and most of its ancillary system, is shown in this recent photo.

Office of Energy Research (ER). Following permission by Secretary of Energy James Watkins to resume startup operation in January 1990, full power was reached on May 18.1990. Ongoing programs have been established for procedural and technological upgrade of the **HFIR** during its operating life. The HFIR completed its 300th fuel cycle on September **17, 1991.** This event was celebrated with an appreciation party the following week for all those contributing to the **HFIR's** success.

Since it began full-power operations in 1966, the **HFIR** has been one of the world's most powerful research reactors. The **HFIR** is a beryllium-reflected, light-water-cooled and-moderated, flux trap reactor that uses highly **enriched** ^{235}U as the fuel. One of the primary purposes of the **HFIR** is the production of ^{253}Cf and other transuranium isotopes for research, industrial, and medical, applications.



The **HFIR** control room. The various systems of the reactor are displayed schematically in different **colors**— a human-factors enhancement made to the control room since 1986.

7917 office **building.**

Beyond its contributions to isotope production, the **HFIR** also provides for a variety of irradiation tests and experiments that benefit from the exceptionally high neutron flux available. The HFIR is unique in the sense that it provides the highest **steady-**state neutron fluxes available in any of the world's reactors, and neutron currents from the four horizontal beam tubes are among the highest available.

Another major use of the HFIR is for neutron-scattering experiments to reveal the structure and dynamics of a wide range of materials. The neutron-scattering instruments installed on the horizontal beam tubes are used in fundamental studies of materials of interest to solid-state physicists, chemists, biologists, polymer scientists, metallurgists, and colloid scientists. These instruments are open for use by university and industrial researchers on the basis of scientific merit. Each year about 150 to **200** researches use the experiment facilities at the HFIR.

Notable accomplishments resulting from HFIR operation include the production of **^{252}Cf** and other heavier transuranium elements, including picogram quantities of **^{257}Fm**. Production of these products are used for direct studies in nuclear and inorganic chemistry and solid-state physics. They also are used as targets in heavy-ion accelerators for the synthesis of still heavier elements and their isotopes, which are used in research. Engineering uses of ^{252} Cf also have been developed and include use as reactor startup sources, scanners for measuring the fissile content of fuel rods, neutron activation analysis, and fissile isotopes safeguards measuring systems. In addition, **^{252}Cf** used as a medical isotope to treat several types of cancer. Also, neutron activation analysis at the HFIR has been used by the semiconductor industry, environmental remediation operations, and the Food and Drug Administration. The fusion Energy Program has been supported by the **HFIR** in three major areas, including neutron interactive materials (structural materials and ceramics), high heat flux materials, and plasma interactive materials.

The neutron-scattering facility at the HFIR has provided support basic research programs involving neutron scattering from polymers, colloids, magnetic materials, alloys, superconductors, and biological materials.

Many changes have taken place in the **HFIR's 25-year** existence. Compliance, quality assurance, training, as well as several other areas have come under extreme scrutiny form DOE. The implementation of procedures such as expanded occurrence reporting and total quality management (TOM) and responses to continuous audits, reviews, and new requirements have created the need for additional personnel and operating funds. When first started, the HFIR supported a staff of 48 to 50 people, **half** of whom were support staff from other **ORNL divisions** such as the Plant and Equipment and Instrumentation and Controls divisions.

The cost to build the reactor and cooling tower was a mere $14.7 M, and **HFIR's first** operating budget totaled approximately $2.3 million. In 1986 the HFIR operated on a budget of $10.9 million and supported 56 division and nondivision personnel. The impact of the many changes is reflected by the 1992 **HFIR** operating budget, which is expected to reach $35 million with 194 personnel supported. The operations and maintenance staffs have increased, as well as support sections for reactor engineering and safety analysis, compliance, training, management technology, and quality assurance.

Future plans for the **HFIR** include fuel testing for the Advanced Neutron Source.

HFIR Fuel Elements

In its early years of operation, fuel at the HFIR was stored on the second floor. As many as 45 fuel elements were stored behind "chicken wire" fencing. The fencing was the extent of security at that time. The gates to the **HFIR** site were left open, with no guard or access control. When elements needed to be taken to the Y-12 Plant, reactor operators drove the elements, in barrels, on a truck to the Y-12 Plant without escort or notification that elements were being moved. Today access to **HFIR** is tightly controlled.

"Beam Me up Scottie"

During the 1987 **strikes,** engineers, technicians, draftsmen, and other personnel were "drafted" to work on shift at the reactors as 'junior reactor operator apprentice trainees." One of these engineers was known to have been performing shift checks at the **HFIR** cooling tower and radioed into the control room, "Beam me up, Scottie." A far cry from today's formality of operations.

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