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The History of Reactor Operations

INTRODUCTION

The atomic era was born with the world's first nuclear chain reaction experiment, Chicago Pile 1, conducted at West Stands of the University of Chicago's Stagg Field. The scientists, engineers and technicians who made this experiment a success were the world's first reactor operators. The present Argonne Reactor Operations Division finds its roots deeply entwined in the memorable events which occurred at this birthplace of nuclear power. The Division is a direct descendant of Chicago Pile 1 (CP-1) operations in both purpose and personnel, yet its unique history has never been assembled and presented in a comprehensive form.

The purpose of the Reactor Operations Division is and has always been to safely and efficiently operate Argonne's on-site research reactors. Only the methods used to attain this objective have altered over the years with the advent of the more sophisticated reactors, the more stringent operating codes and restrictions, and the explosion of paperwork.

This publication is designed to demonstrate the evolution of Argonne's reactor operations from the world's first nuclear reactor at West Stands to the present.

THE BEGINNING - CHICAGO PILE 1

On December 2, 1942, the first self-sustaining nuclear chain reaction was achieved and controlled, thereby initiating the controlled release of nuclear energy. This event has been denoted "the greatest achievement of organized science in history" by the late Secretary of War, Henry L. Stimson. This event was the birth of the atomic age.

The pile, Chicago Pile 1, was constructed in a squash court in the West Stands of the University's Stagg Field by a small group of physicists and engineers, headed by Dr. Enrico Fermi of the University of Chicago's Metallurgical Laboratory. Dr. Fermi was recipient of the Nobel Prize in Physics in 1938. The purpose of the Metallurgical Laboratory was to research the possibility of a self-sustaining chain reaction and its application to the possible nuclear synthesis of plutonium for bombs.

Because of the secrecy of the project, "Metallurgical Laboratory" was chosen as a code name for the scientific experiment at the University of Chicago. The Lab was initially under the jurisdiction of a governmental agency, the Office of Scientific Research and Development, but was later (June 1942) turned over to the Army Corps of Engineers' Manhattan District Project, headed by General Leslie R. Groves. The University of Chicago was the contracting group. All persons working on the project, including technicians and guards, were disguised as researchers--staff members of the university--and were granted all staff privileges, such as attending the Staff Club.

Fermi was assisted principally by two groups, headed by Dr. Walter H. Zinn and Dr. H. L. Anderson, which handled the actual construction of the graphite-uranium pile. Program planners, such as Dr. Norman Hilberry, predicted what men, money, and materials would be needed--and had them ready at the proper time without attracting attention. No outsiders could know the nature of the project. Thomas Brill was a member of the circuit group, concerned with monitoring and controlling the pile. Herbert Kubitschek (BIM), Al Wattenburg, Harold Lichtenburger, and Robert Nobles (IDAHO) were among those who performed the principal measurements of materials used in constructing the pile to assure that critical dimensions were not reached inadvertently. All these persons later played distinctive roles in Argonne's reactor development.

The early graphite reactors, CP-1 and those to closely follow, were known as "piles" because of their particular construction. CP-1 was actually just a huge pile, 24' wide, 24' long and 19' high, of machined uranium and graphite blocks erected upon a wooden frame. Alternate layers of graphite, containing uranium metal and/or oxide, were separated by layers of solid graphite blocks to form a lattice structure. It contained 385.5 tons of graphite and 46.5 tons of uranium metal and oxides.

The construction of the pile was originally planned for the Argonne Woods (later designated Site A), but slow construction of the building to house the pile and the government's wish for expediency changed the plans to the largest space available, the West Stands. Construction of the pile commenced early in November, 1942. By December 2 at 2:35 p.m., just one month later, the control rod was withdrawn, and CP-1 was brought to criticality. Just a few minutes later, at 3:53 p.m., the control rod was pushed in and the self-sustaining chain reaction was stopped. If harnessed, the energy produced was only enough to light a bulb, but man had unleashed and controlled the energy of the atom. Fermi was presented a bottle of Chianti to celebrate the event. All present signed the wicker basket surrounding the bottle. These signatures are the only record of those present at the historic event.

The pile was operated at a maximum power level of 200 W, since higher level operation of an unshielded reactor might conceivably prove injurious to the operating personnel. Operation was terminated on February 28, 1943, after only three months. Because of the dense population near the stands, it was felt the reactor must be dismantled and moved away from the city. Extremely valuable basic information had been acquired at CP-1, however, despite its short existence.

CP-1 Becomes CP-2

The building at Site A (a remote section of Argonne Woods in the Cook County Forest Preserve) was now completed and ready to house the reactor. The experimental reactor work could now be accomplished in an isolation not obtainable in the city. Because of its location, this branch of the Met Lab became known as Argonne Lab. Later when the Met Lab was reorganized, this name was adopted for the entire laboratory.

Al Wattenburg was in charge of dismantling CP-1; Robert Nobles and Harold Lichtenburger were in charge of reassembling the reactor, which was then retitled CP-2. This entire evolution took only 21 days. On March 20, 1943, CP-2 began operation with the explicit purpose of procuring design data for the plutonium-producing Oak Ridge X-10 and Hanford reactors. CP-2, also a uranium-graphite reactor, was a slightly modified version of CP-1 equipped with a radiation shield for protection of the operators. CP-2 was actually a completed version of CP-1, as it would have originally been constructed if Site A had been ready at the crucial time.

The New Site

Site A, leased from the Cook County Forest Preserve, was situated in a remote and wooded area covering approximately 1000 acres. Archer Avenue, 107th Street, and Wolf Road served as boundaries; only a small inconspicuous sign, "103rd & Archer," marked the entrance to the highly secret site. A winding tree-lined road led the mile and a half from the entrance to the reactor area.

Site A was fondly referred to as "The Country Club," for the Palos Park Golf Course had been located there prior to World War II. Building A, which housed CP-2, was located near the No. 2 green. There were tennis courts, a ping pong table in the cafeteria, and a guest house. Baseball and football were common noontime activities, and who could resist a little golf after work on some of the remaining fairways. When the Reactor Development Section of the Met Lab first moved to Site A, a single building housed the reactor, laboratory facilities, a library, a machine shop, nurses' quarters, a lunch room, and a dormitory. This was a handy arrangement for the personnel--especially in the winter months. The people at the site, including scientists, guards, cafeteria workers, etc., numbered only around 100, so a definite air of informality reigned.

CHICAGO PILE 2 (CP-2)

Dr. Walter H. Zinn was in charge of Site A, including all reactor development and operation. The new site, however, was "Fermi's Laboratory," where he continued his work started at the CP-1 experiment. It had an existence apart from the rest of the

Met Lab, and Enrico Fermi, who loved the out-of-doors, enjoyed the location and the isolation. He was always there and was always accompanied by his body guard, John Baudino, a lawyer by trade. John helped employees with income tax forms and other legal matters while he waited for Fermi day after day. Fermi made all the reactor theoretical calculations and decisions until after the next reactor, CP-3, went critical. With Fermi's departure for the Hanford startup and for his responsibilities at Site Y (Los Alamos) in late 1944, Dr. Zinn truly assumed the leadership of Site A.

In the early years of its existence, CP-2 was operated by members of the scientific team--most of whom were present at CP-1. No one was hired specifically to operate the reactor, and no one was directly responsible for its operation. The reactor was strictly an experimental tool; whoever was conducting the experiments also operated the reactor. The keys were in the hands of Charles Eggler (PHY), then a member of the Army's Special Engineer Detachment. H. L. Anderson, Al Wattenburg, Harold Lichtenburger, Leona Woods Marshall, John Marshall, and Enrico Fermi, all present at CP-1, were experimenters on CP-2 and later on CP-3. Robert Nobles (IDAHO), also from CP-1, often operated the reactor for the experimenters.

Description

CP-2, by nature of its uranium-graphite construction, was about three times the physical size of the present CP-5 research reactor. It was 30' wide, 32' long, and 21' high, containing 472 tons of graphite and 52 tons of uranium. The top of the reactor was covered with six inches of lead and four feet of wood. A small laboratory, dubbed "the penthouse," was erected on the top in which experimental work was performed using neutrons generated within the reactor.

The reactor area was equipped with a portable construction elevator which ran from the main floor to the top of the reactor, about three levels. It was used for transporting graphite, equipment, and personnel. The elevator consisted merely of a flat platform, completely open on three sides, thus its passengers considered the ride quite a hair-raising experience.

The various control and safety rods entered the sides of the reactor from supporting platforms built around its faces or sides. Numerous openings were available in the front face so that blocks of graphite, known as stringers, could be removed and test materials inserted into the active area of the reactor.

Compared with later reactors, CP-2 had few controls. Instrumentation consisted primarily of two galvanometers, which recorded neutron flux (from which the power level could be calculated), and a temperature-measuring device to determine the thermal heat in the graphite. Excessive heat in the graphite was one of the reactor's primary problems. There were no cooling or ventilation systems.

A safety circuit existed which would automatically shut down the reactor if a preset power level was exceeded. This circuit could be easily bypassed, however, by propping up the controls with a lead brick--and this was done occasionally. If an experimenter wished a higher than normal power level for a special experiment, the preset level was bypassed--within reason. The experimenters at CP-2 were still curious about what reactors could do, so they experimented by exceeding the set rules for timed periods, power levels, etc. Today, similar things can be done, but not without a very involved procedure and a lot of red tape.

Operation

Compared to the modern research reactors of today, CP-2 was operated at an extremely low power level, normally around 1 kW, although the level was occasionally upped to 5 kW or even 10 kW for special high power runs.

To start operation of CP-2, the operator had to enter the reactor area, climb up one level and go out a catwalk to the reactor for the manual part of the procedure. One shim rod had to be withdrawn manually. This rod, normally locked in the "in" position, was pulled out along a graduated meter-type stick. When it reached the position designated for the particular desired reactivity range, the rod was relocked in this position. (At shutdown, the last thing to be done was to insert this rod and again lock it in the "in" position.) A hollow graphite stringer could also be cranked out manually, loaded with fuel, and reinserted to alter the fuel loading of the reactor. It was also possible to insert samples by this method; in fact, some experimenters hollowed out their own graphite stringers to fit their particular sample shapes.

The remainder of the operation could be handled from the basement control room at a control panel crudely erected upon two wooden desks. By pushing two buttons, the reactor's two shim rods were automatically pulled from the "full in" to the "full out" position. Indicator lights showed when this evolution was completed. There were two cadmium control rods, one of which was controlled by special Amplidyne motors and represented on the control panel by two brass indicator dials and a crank. The crank was turned a set distance, then the galvanometers were watched until the power level stopped rising. This was repeated until the desired power level was reached. The periods were quite slow, because of the reactor's small amount of excess reactivity. The other rod for finer control was regulated by a lever protruding from the floor in front of the reactor console. These electrically-operated control rods were actually mechanically moved in and out by bicycle-chain-type linkages. Should the chains become fouled up, manual operation was possible.

The control room for CP-2, located in the basement of the reactor building, and the ground level reactor area were connected by a PA system to allow communication between the two areas. The system was crude, however, and often lung power won out over the ineffectual PA network. In the summers, Dr. Zinn quite often slept overnight in the basement control room. It was extremely cool and air-conditioning was a real luxury at that time.

Experimentation

The reactor was operated only when needed by experimenters and had no set operating schedule until around 1950. Occasionally, experimenters would start up the reactor, get involved in their work, and leave the reactor operating unattended. This was of no real consequence for the power level of the reactor was so low.

Dan Hughes, with his assistant Ed Bragdon, conducted many experiments on CP-2. George Monk and Rueben Fields used the reactor for metals testing. Uranium was checked for purity by the danger coefficient method to obtain information for the Hanford project.

In these tests, the reactor served as a yardstick. The length the control rods had to be pulled to obtain a certain reading on the galvanometer was compared with and without sample insertion. The results gave an indication of purity and helped in obtaining absorption and fission cross sections. Much of the early information on isotopes and radioactivity in the Handbook of Chemistry and Physics was derived from tests on CP-2.

Aluminum tongs were used to insert samples into the reactor and to withdraw the irradiated samples. The reactor was not shut down for the sample insertions because of the low power levels.

Around 1951, the Naval Reactor Group, headed by the then Captain H. G. Rickover, requested special runs on CP-2 to obtain information for submarine reactors. Set up in the "penthouse," they did core testing on a small scale, checking the flux levels in the core. A lot of Navy Brass roamed the area.

Under today's specifications and controls, CP-2 probably could not be operated. With today's sophistication, the early operation and control seem crude. This, however, was the world's first and only reactor. There were no guidelines to follow and no previous knowledge to incorporate. The operators (experimenters) were the most knowledgeable people in this area of physics. Their knowledge, however, was theoretical; the practical knowledge still had to be acquired. Safety and operating procedures could be developed only by experimentation with and increased use of the reactors.

CP-3, A NEW REACTOR CONCEPT

By midsummer of 1943, a second reactor was being constructed at Site A. This reactor, known as CP-3, was designed and built as an alternative design for the Hanford project, in case major unforeseen difficulties should arise when the Hanford plant went into operation. There was a possibility that graphite-moderated nuclear reactors could not produce the fissionable material required for the Manhattan Project program. CP-3, the world's first heavy-water moderated reactor, used natural uranium for fuel. For a long time, CP-3 had the highest neutron flux of any research reactor in the country. It provided radioactive materials for many important research projects.

Dr. Enrico Fermi was thoroughly involved in the design and construction of, and later in experimentation on, CP-3. He made the majority of the theoretical calculations and decisions and assumed unofficial command. Robert Nobles, under Fermi's direction, made all the drawings of CP-3 for the vendors and suppliers. He later worked on drawings for CP-1 and CP-2 for the originals (what there were) had been discarded. Since Nobles is an engineer, not a draftsman by trade, the drawings were all systematized at a later date.

Description

CP-3 was built quite close to CP-2, separated only by a hallway. With less than a year from ground-breaking to operation, the reactor went critical on May 15, 1944. In connection with CP-3, three more buildings were erected. Site A was becoming a nuclear research center by the summer of 1944.

In contrast to the existing massive graphite-moderated reactors, CP-3 was physically quite small. It consisted of an aluminum tank, 6 feet in diameter and nearly 9 feet high, containing 1500 gallons of heavy water and 120 uranium metal rods, 1.1 inches in diameter and 6 feet long. This reactor core was surrounded with a concrete shield, octagonal in shape, 13 feet high and 8 feet thick. Numerous openings, closed by removable plugs, penetrated the concrete shield to provide facilities for measuring the neutron intensity, for exposing materials to radiation, and for permitting the passage of beams of radiation from the reactor.

Unlike its predecessor, CP-2, CP-3 had provisions for removing the heat created during the fission process. The heavy water was pumped from the top of the reactor, passed through a heat exchanger, and returned to the reactor tank through an opening at the bottom of the tank.

The reactor, normally operated at a full power of 300 kW, was usually taken to power or scrammed in approximately seven minutes. Enrico Fermi, curious about what the reactor could do, however, once requested that CP-3 be taken to power as quickly as possible and leveled off at 300 kW. Dr. Zinn forcefully asserted that this could be done in 10 seconds. But after numerous tries by Fred Cokeing (RO), H. Lichtenburger and finally Dr. Zinn himself, Zinn had to admit it couldn't be done--but it was close.

Some instrumentation, not found on CP-2, was added to the controls of CP-3, primarily because of the nature of the reactor. Both temperature and flow sensing indicators were required for the primary and secondary systems. A safety shut-off system was incorporated whose operation was initiated when the galvanometer reached a preset level. A heavy-water inlet temperature trip, which was quite sensitive, was sometimes accidentally tripped. Occasionally, when the tile floor (or possibly the control room counter top) was being buffed, the floor buffer would hit the control panel, jostle the inlet temperature recorder, and scram the reactor. An automatic control rod system, regulated by a galvanometer light spot situated between two photo cells, adjusted the control rods for slight fluctuations once the desired power level was reached.

Even with these additions, there was very little instrumentation. Perhaps it was lucky that no real crisis ever occurred. Of the controls that did exist, however, some were only occasionally used; others were never touched. Great care was taken in establishing acceptable operating conditions, and there were no major incidents. Everything ran relatively smoothly.

The operation of CP-3 seemed quite sophisticated when compared to the operation of CP-2. Under normal circumstances, the operational procedures could be handled almost completely from the control room with no need to enter the reactor area.

Operators

At the time of CP-3's completion, Site A was still part of the "Met Lab" of the University of Chicago, and thus was under the jurisdiction of the Army Corps of Engineers. Walter Zinn still headed Site A, assisted primarily by Dan Hughes (Brookhaven) and Gale Young (PHY). Army personnel, who had helped with the construction of CP-3, became its first operators. Two army sergeants, Lee Lawhead and Robert Best, operated the reactor from its completion in May of 1944 until November of 1945.

At this time, Alfred F. Cokeing (RO), the first civilian reactor operator, was hired to relieve some of the Army personnel. Samuel Bain was also hired within a short time. These operators were hired on a six-month probation basis. The policy was--if you couldn't perform, you left. The Army personnel trained the new operators.

CP-3 was then operated only on a day shift by Sam Bain and Fred Cokeing. This day shift, however, kept increasing to about 16 hours by mid 1946, so two more operators were hired, James E. Slattery (RO) and Russel D. Morley (AEC). When these operators were trained, the Army personnel left the site. (Elmer Rylander (LDO) and Miles Sharpess, at Site A at the time, also operated the reactors, primarily CP-2, but they were not a part of the reactor operations organization.)

CP-3 operation then went to two shifts, with two operators per shift. The reactor was run from 8:30 a.m. to 11:00 p.m., Monday through Friday. At 11:30 p.m., a car was provided to take the workers back into Chicago.

Increased demand for use of the reactor created frequent Saturday work and late nights, so three shifts were organized in May 1947. The reactor was then run around the clock from Monday morning through 5:00 p.m. on Saturday. At this time, Octave John Daniel (RO) was hired, followed by Joseph I. McMillen (AEC)(November 1947), Robert Dahleen (January 1948), William R. Treharne (RO)(March 1948), Earl T. Cobb (RO)(1949), August A. Schulke (RO) (1950), Frank Nolan (1950), and Albert W. Pierce, Jr. (RO)(1952). This was the core of pile operators throughout Site A's existence.

The training for these pile operators at CP-3 was on-the-job training and was practically nonexistent. A new operator started to work alongside an experienced operator and learned primarily by observation. There were no set training programs, qualification procedures, or testing schedules as there are now. When the trainer felt the new operator was ready, the reactor was all his--and this could occur on about the first day. "So long, I'm off to lunch."

The operators of CP-3 were responsible for sample preparations, sample irradiation, the neutron flux, maintenance, removal and loading of samples into lead containers (for the Special Materials group to ship), and reactor heavy-water analysis.

The operators handled all the reactor maintenance. There was no set maintenance program or checks. When something went wrong or needed to be replaced, the reactor was shut down and everyone stood back while it was fixed.

Today, paperwork has increased a thousand fold over that required at CP-3. The main record was in a very simple logbook--a small, brown-covered notebook. The entries consisted merely of a stamp where the operator filled in "reactor up" time, power level, and time the reactor was shut down. All other information was passed by word of mouth from one operator to another. When the operation was organized into three shifts, the word-of-mouth communication became quite complicated, and a written record was needed of what was and was not accomplished during each shift. A more complete log book recording system was then developed.

Walter Zinn originally handled the hiring of the reactor operators, and he seemed to consider them his chosen few. Although he had a tremendous "bark," he seemed to feel that the operators could do no wrong. Other personnel around the Lab were often fired or reprimanded for the same actions that he excused in the reactor operators. His real interest was the reactor development area. To show his other side though, Dr. Zinn was an extremely forceful individual who ruled with an iron hand. Everyone considered his word as law and carried out his orders immediately--even if received third hand. If a project was to be done by 5:00 p.m. tomorrow, it was done by 5:00 p.m.--no matter what.

The tight security which surrounded the reactors at Site A, necessary because of World War II and the secrecy of the project, greatly complicated the hiring of personnel. The hiring process often took a couple months because Q clearances were required for operation of the reactors. And besides the Q clearances, the badges were further color-coded. These color codes restricted personnel to specific areas of Site A. For instance, a particular color was required to enter the reactor building. Some of the new operators were put on temporary jobs until they received their Q clearances. In other cases, if the need was great enough, new employees were allowed to start operating the reactors immediately, but with absolutely no idea of what they were really doing. Most had no idea of what a reactor was until they had actually operated one. Operators no longer need security clearances for their work.

In addition to all the security clearance restrictions, a guard was posted at the control room door around the clock. A List of Admittance on the door designated those who could enter, and there were no exceptions. One day Lab Director Dr. Zinn, along with a number of other people, came to tour the reactor area. Everyone's name was on the List of Admittance, but Zinn's; the guard allowed everyone to enter, but Zinn.

Zinn, saying, "What do you mean I'm not on the list, I signed it," rushed back to his secretary and had a supplemental list drawn up---with his name at the top.

On his way out after touring the area, Dr. Zinn said to the guard, "Good thing you didn't let me enter. I'd have come back out and fired you."

Experimentation

The main use of the reactor was sample irradiation. On the roof of the pile was a hole called a "thimble" surrounded by lead blocks through which samples were inserted into the pile for neutron bombardment. For one series of experiments, an oscillator, built by Alexander Langsdorf (PHY), was placed on the top of the reactor. This oscillator was originally designed just for inserting and retrieving samples from the reactor core at set time intervals to ensure uniform and controlled irradiations. However, it was noted that the movement could also be recorded on the reactor power control instruments in the control room. When the sample was inserted, the power level of the reactor was changed accordingly. Thus the oscillator found significant use in studies of core physics. This oscillator is now in the collection of the Smithsonian Institute in Washington, D.C.

A facility located on the side of the reactor, called a goat hole (isotope tray on CP-5), and the thermal column were also used for sample and specimen irradiation.

Materials that quickly lost their radioactivity and had to be handled rapidly were inserted through a rabbit tube by a vacuum system. After irradiation, they were blown out with air pressure and caught in a waste paper container. On one occasion, a sample became lodged in the tube. The air pressure was increased; the sample finally broke loose, came out with tremendous force, struck a support pole, and shattered. The spilled radioactive material on the experimental floor was impossible to clean up. The final result--a new floor.

Many experiments, outside the line of duty, were conducted on the reactors. There was an attempt by the resident "alchemists" to produce gold from mercury. The experiment was successful, but the gold was so "hot," it couldn't be touched for years. Paper was inserted in the reactor and irradiated, producing a pastel talcum-like powder. Irradiated nickels and quarters were used for handouts to visitors touring the reactor area. When discovered, this practice was soon curbed.

To schedule an experiment, the experimenters signed up for the times they wanted on a blackboard near the reactor area. Friday morning was the signup time. An experimenter could request a time up to two weeks in advance. The reactor was used nearly to capacity by the experimenters; most of the routine sample irradiations were run during the off shifts. Some of CP-3's key experimenters, who are still at Argonne, are George Thomas (PHY), Carl Hibdon (PHY), Lowell Bollinger (PHY), William Bentley (CHM) and Paul Persiani (RP).

ARGONNE--THE FIRST NATIONAL LABORATORY

In 1945, after the end of WW II, the Corps of Engineers appointed an advisory committee to review the Laboratory's proposals and prepare a definite plan for the Lab's future operation entitled Plan of Organization and Statement of Operating Policy for Argonne National Laboratory. It was proposed that the continuing laboratory be called Argonne National Laboratory since the Metallurgical Laboratory had been just a code name--a security measure.

The new plan was adopted, and Argonne National Laboratory, the first national laboratory, began its official existence on July 11, 1946, with Dr. Walter H. Zinn as Laboratory Director. Dr. Harold Lichtenburger was placed in charge of reactor development. The present DuPage site (Site D), five miles from Site A, was designated as the permanent laboratory location at that time.

In the meantime, Congress had been debating the national organization of the Atomic Energy Project. In August of 1946, President Truman signed the Atomic Energy Act of 1946 and immediately appointed the Atomic Energy Commission. The Corps of Engineers then turned over Argonne National Laboratory to this commission.

As a result of an AEC decision on January 1, 1948, the Laboratory was requested to assume the responsibility of serving as the Commission's principal reactor development center--in addition to its other research and development responsibilities.

FIRST RO ORGANIZATION

As a result of this increased emphasis on reactor development, the first official organization of a reactor operations group was formed on August 1, 1948, as a section under the Reactor Engineering Division. Dr. Zinn selected Dr. W. H. McCorkle to set up and head the new group, called Pile Operations. McCorkle had joined the Met Lab in 1944, working in Chicago on optical instruments (periscopes used for inspections at Hanford) until he joined the reactor group at the site around 1946. Since Zinn had been so involved with the reactors and the reactor personnel were his chosen few, McCorkle reported directly to him.

The group first consisted basically of Dr. McCorkle, his secretary, and six reactor operators (previously named), but it was a separate group with specific duties. McCorkle soon acquired an administrative assistant, Carl Benz. From the title Pile Operations, the reactor operators became known as DOPES--Doctors of Pile Engineering. And Doctors they truly were, for they knew more about pile operation than any other group in existence.

Dr. McCorkle had a personality quite opposite that of Dr. Zinn. He was extremely quiet--to the point of sometimes being difficult to talk to. He also was very patient; "Goodness Gracious" was one of his strongest expressions. Yet he had a firm grip on his group. When he wanted something done, it was done on time, and it was also done "Mac's" way.

CP-3 MODIFIED TO CP-3'

In 1950 after more than six years of almost continuous operation, CP-3 was overhauled, refueled, and retitled CP-3'. This was the first reactor refueling in history. There were no outside contractors; the operators handled the whole conversion, essentially tearing apart and rebuilding the entire reactor.

The original fuel rods were replaced with enriched-uranium fuel in which the ratio of fissionable uranium-235 atoms to nonfissionable uranium-238 atoms is greater than that found in nature. The power output of the reactor was reduced from 300 kW to about 275 kW, but the converted reactor produced a higher neutron flux.

The refueling took place in miserable February weather, and the fuel elements had to be stored until they could be processed. An isolated area of Site D was chosen for the storage location. Pipes were sunk in the ground in the same arrangement as the fuel rods in the reactor core. The elements, which were loaded individually into lead coffins, were then transported from Site A to Site D one at a time in the back of a canvas-covered Army truck and placed in the sunken pipes. It was a long, tedious task for there were 121 elements. In addition, some of the elements were warped and wouldn't slide into the pipes without prodding or being cut up with a hacksaw.

Plus the refueling, the instrumentation was also updated with the installation of the first period instrument. This period recorder was so sensitive, it was nicknamed "Nervous Nellie." The reactor was not really properly set up for such a sensitive device. A new control circuit was also tested, which is now used on CP-5.

The organization of the Pile Operations Group was altered slightly at this time. Prior to CP-3', all the reactor operators were considered to be on the same level. With the completion of CP-3', a new senior reactor operator position was formed. W. H. McCorkle assigned Fred Cokeing, O. J. Daniel, and Joe McMillen as the senior operators to head each shift. The operators' duties were also expanded to include operation of CP-2. Since CP-2 was run on a request basis and since there were three men on CP-3's day shift, one operator would leave CP-3 to run CP-2.

LRRO IS FORMED

Two years later, January 1, 1952, the Pile Operations Group became the Laboratory Research Reactor Operations Division (LRRO). It was no longer under the Reactor Engineering Division, but was an established scientific division, still headed by Dr. W. H. McCorkle.

The new division was formed with the explicit purpose of operating the Laboratory's on-site research reactors. CP-2 and CP-3 were operating and plans were underway for the construction of a new and advanced research reactor, CP-5.

SITE A ERA ENDS

Between 1946 and 1950, Argonne had grown immensely in scope and in personnel, and Site A was extremely crowded. Several of Argonne's present divisions were then at Site A.

By 1951, all the administration quonsets and most of the research buildings at Site D were nearing completion, and Site A was nearly evacuated. After 1951, the LRRO Division personnel and those whose work required them to be close to the reactors were the only ones remaining at Site A. With the construction and completion of CP-5 in February, 1954, most of LRRO moved to

Site D, leaving only a skeleton crew of Cokeing, Cobb, and Treharne to man CP-3.

Site A was closed down as an operating unit on May 15, 1954, the 10th anniversary of the day CP-3 first began operation. Both the graphite reactor, CP-2, and the heavy-water reactor, CP-3, were taken out of service on that day. CP-2 had been in good operating condition for 11-1/2 years; CP-3 for 10 years. Both had greatly outlived their expected life span, a definite tribute to the excellence of the reactor operation personnel. The Laboratory Director, Dr. Walter Zinn, who first made CP-3 go critical, pressed the button which closed it down for good.

Approximately a year after their operation was discontinued, the two world-famous reactors were dismantled and buried.

The graphite from CP-2 was sent primarily to the Smithsonian Institute, where a replica of CP-1 was to be built from the original CP-1 materials. A mockup of CP-2 was also constructed. Some of the remaining graphite has been shaped and mounted into souvenirs of CP-1.

The buildings housing the reactors were removed before final disposition of CP-3'. A 40' hole was dug beside and partially under CP-3' after removal of its uranium fuel. After the blasting of 250 lbs of dynamite, CP-3', weighing 800 tons, slid into the bottom of the excavation where it was covered with a shield of concrete. A smoothly-graded surface, marked only by a plaque, designated the remains of CP-2, CP-3', and the buildings at Site A which housed them. The Site A era had come to a close.

CP-5, ARGONNE'S RESEARCH REACTOR

Because of improvements in reactor technology and demands for high neutron flux, and because CP-3' was five miles from the rest of the Laboratory and on land leased from the Cook County Forest Preserve District, construction was begun on a new reactor at Site D in the fall of 1951.

CP-5, built under the direction of Project Coordinator W. H. Zinn, went critical on February 9, 1954, and started continuous operation on March 1 under Dr. W. H. McCorkle, head of LRRO. Joe McMillen served as the first Facility Supervisor.

one megawatt March 1, 1954 16:30 hrs.

CP-5, a refined version of its predecessor CP-3', uses enriched-uranium fuel and is cooled and moderated by heavy water. CP-5's sole purpose is to provide abundant radiation--primarily neutrons--for research. Primary emphasis is on beam experiments.

On March 20, 1954, Argonne held its first open house--specifically to show off its new reactor. Approximately 2,200 people visited CP-5 that day, viewing the reactor from a balcony which encircles it. Throughout its existence, CP-5 has been a gracious host to visitors. No one tours the Lab without stopping to look at the reactor. By 1964, its 10th anniversary, CP-5 had accommodated over 100,000 guests; today, more than 132,000 persons have toured the facilities from literally all over the world. Registered in the guest book are persons from India, Australia, China, Venezuela, Nigeria and Sweden, to mention a few. The volume of visitors per year, however, has dropped somewhat in recent years. The Laboratory now restricts the tours to groups it believes will actually benefit from the experience. For example, instead of admitting entire high school classes anxious for a day off from school, only such groups as the science clubs are allowed to tour. Restrictions have also been placed on persons under 18 years of age.

CP-5 is not glamorous in appearance; it has been coined the "workhorse" of the atomic age. The reactor has proved to be one of the country's most useful sources of information about the atom. It has performed reliably and powerfully and has displayed extreme versatility, earning the title of "the bread-and-butter reactor of Argonne."

Shaw, Metz and Dolio, architects for the building which houses CP-5, Building 330, received a Citation of Merit in 1956 from the Chicago Chapter of the American Institute of Architects and the Chicago Association of Commerce and Industry.

The reactor design has served as a model for heavy-water reactors all over the world. Reactors of the CP-5 type are in operation in Japan, Italy, and England, and in the United States at Massachusetts Institute of Technology, Georgia Institute of Technology and Iowa State University.

In addition to its primary role of accommodating experimenters, CP-5 contributed to the development of nuclear fuels for the Experimental Breeding Reactor II at Argonne's Idaho site and for the Enrico Fermi Reactor at Monroe, Michigan. It provided startup sources for the Elk River Reactor in Minnesota and Argonne's EBWR, JUGGERNAUT, JANUS and ARGONAUT reactors. It has served as a training ground for teachers and operators all over the country.

CP-5 has definitely played a unique role in reactor history. It is now and is likely to remain one of the country's most useful research reactors.

Description

Inside the cement block that visitors witness is the real heart of the reactor.

The core is 2' in diameter, 2' high and is composed of seventeen fuel assemblies located in the center of a 6' diameter aluminum tank. The tank, filled with heavy water, has entrance and exit piping for circulating the heavy water to the cooling system. Approximately 1800 gallons of heavy water per minute are pumped through the core. A 2' thick zone of graphite blocks surrounds this tank and a 10' diameter steel tank encompasses the aluminum tank and the graphite. Around the steel tank is a 3" layer of lead. Between this lead and the outside steel faces of the reactor, special dense concrete has been poured for radiation shielding. There is also shielding material above and below the reactor.

Operation

CP-5 was originally designed for operation at one megawatt. After two years of operation, in July of 1956, CP-5 was shut down for modification to permit operation at two megawatts. A power level increase was desired because requests from experimenters were so great CP-5 could not begin to satisfy them. The fuel elements were also modified, permitting sample irradiation directly inside the elements. The new elements consist of three concentric fuel-bearing tubes clad with aluminum. At this same time, a gravity-feed emergency cooling heavy-water reservoir was installed over the reactor top shield. In 1960, CP-5 was further modified to allow routine operation at power levels up to five megawatts.

Operation at a 5-MW power level gives a slow neutron flux of about 6 x 10^{13} neutrons/cm^2/sec in the region of highest flux. In comparison, CP-3', which had a power rating of 275 kW, had a slow neutron flux of approximately 3 x 10^{12} neutrons/cm^2/sec. CP-5 has now registered over 265,000,000 kilowatt hours of operation.

Operational control is furnished by three systems. Large amounts of reactivity are handled by four semaphore-type shim-safety rods. These rods, which are aluminum-clad cadmium plates, fall into the core in 300 to 500 milliseconds with initial acceleration provided by springs. Running control of the reactor is provided by a cylindrical regulating rod operating in a vertical thimble in the heavy-water reflector. Backup shutdown control is provided by automatic or manual dumping of the heavy-water reflector above the reactor core.

Cooling is supplied by pumping heavy water into a plenum at the bottom of the reactor tank. The coolant then passes through orifices in the bottom of the fuel elements, travels through the elements and finally discharges into the tank. Heavy water leaves the tank by an overflow and passes through a light-water-cooled heat exchanger for heat removal. Since the tank is not operated full of water, a helium atmosphere is maintained over the heavy water to aid in controlling coolant quality.

Because of the large heat capacity of the tank of heavy water, it is possible to dispense with pumps or other machinery for shutdown cooling. Thus operators are not required to be in attendance if the machine is taken out of service for a short time.

Compared to the control rooms of CP-2 and CP-3, CP-5's is a maze of dials, buttons, meters and closed-circuit television monitors. As the reactors become more and more complex, more knowledge of plant parameters is required to increase safety and to obtain a total picture of plant events. Most control operations of the reactor, including the manipulation of valves, pumps, and flow systems, are centralized in the control room adjacent to and overlooking the reactor area. A main feature of the control system is that most vacuum tubes and electronic components are also concentrated into this area. An annunciator board provides visual indication for the malfunctioning of any detectable points in the system. The reactor is designed to shut down should an abnormal condition arise.

When CP-5 first began operation in early 1954, CP-2 and CP-3' were still functioning. All three reactors were run by nine operators: Fred Cokeing, Russ Morley, Bill Treharne, Earl Cobb, Frank Nolan, Al Pierce, Gus Schulke, John Daniel and Joe McMillen. Sam Bain, Bob Dahleen and Jim Slattery had left the operating group, although Slattery soon returned to the Technical Section of LRRO. After CP-2 and CP-3' were decommissioned in May, all the operators moved to CP-5 at Site D.

CP-5 was first operated on a Monday through Saturday afternoon schedule as CP-3' had been. There were six day shifts, but only five night and five mid shifts. No one was required to man the control room during the shutdown time, Saturday afternoon to Monday morning. Two security guards were on duty, one in the containment shell and one at the guard house, but a leak detection system was really the watchdog. This detection system sounded a bell in the building and in the guard house if anything went wrong in the primary system. The guards could then call the operations people for assistance, should it be required.

This schedule was used for about a year, then operation was increased to that of today---seven days a week around the clock.

There are now five normal operating crews, each consisting of a supervisor and three operators. A crew's basic function is the operation of CP-5, which includes manipulating the controls, reading the recording devices, and servicing the reactor and related equipment in the facility. This staff aids in preparing samples for irradiation, keeps irradiation records, and removes and prepares all irradiated samples for shipping. It also assists experimenters in setting up equipment and performs necessary related duties.

In addition, the operators are responsible for the logbook entries, including the control room half-hourly and hourly instrument checks. Even when the reactor is shut down, hourly instrument checks, control room and reactor area checks are required. All fuel loadings, circuit bypasses, and malfunctions must be recorded. An annunciator circuit report is prepared weekly.

This information plus sample data are summarized in the CP-5 Monthly Reports.

New operators joining the reactor operations crew are generally top technical school graduates or discharged U.S. Navy personnel with experience on naval reactors.

Experimental Facilities

The most important feature of CP-5 is its experimental facilities. More than sixty openings penetrate the sides and top of the reactor providing access to the neutrons within the reactor. CP-5 looks like a chunk of concrete, completely encircled by a maze of experimental equipment. The demand for use of CP-5 is so great that physicists, metallurgists, chemists, biologists and engineers, both from Argonne and other research centers, must apply months in advance for use of the reactor's neutrons.

The experimental facilities include eight channels, called horizontal thimbles, which extend through the concrete shield and penetrate the aluminum tank to a point close to the fuel elements. Two more tubes pass completely through the reactor near the core. Small samples can be inserted into the center of each of the 17 fuel elements for irradiation in the region of highest flux. A number of holes penetrate the reactor vertically, providing access to eleven thimbles within the aluminum tank and seventeen thimbles in the graphite reflector surrounding the tank.

CP-5 has two thermal columns, 5' square sections in the concrete shield filled with graphite blocks, which provide slow neutrons for experiments. These columns can be partially disassembled to provide space for irradiating large objects. Two trenches, which pass under the reactor, are used for sample insertions and removals while the reactor is in operation. For irradiated materials which must be removed from the reactor very quickly, pneumatic tubes, called rabbits, pass through the reactor immediately below the core area.

Experimentation

CP-5's experimental facilities are now, and have always been, filled to capacity. There is a constant turnover in experimenters at the various experimental locations, but some of the experiments date back to the startup of CP-5 and a few back to the CP-3 days.

The fast neutron chopper, in existence since the construction of CP-5, has been a valuable instrument for measuring fission cross sections and for time-of-flight studies which tell the scientists how neutrons are captured or absorbed by certain materials. Studies are now aimed principally at the understanding of gamma rays resulting from the resonant capture of neutrons. The chopper operates as follows: Neutron pulses are produced when narrow slits in a turning metal rotor become aligned with a finely collimated beam of neutrons from the reactor. The neutrons from the source travel down a long tube which extends 120 meters from the reactor. The time required for the neutrons in the pulse to traverse the distance (25, 60 or 120 meters) between the chopper and a detector is used as a measure of their velocity. This information is analyzed and stored electronically.

Biologists are still engaged in an experiment that started at CP-3 with 1000 virgin white mice. In this neutron-gamma ray toxicity study, small animals (mice, chickens and rats) are irradiated and the biological and genetic effects are investigated. The effects of the neutrons on the animals are being compared with the effects of X-rays.

A bent quartz crystal capture-gamma ray spectrometer has provided extensive information on nuclear energy states, fine structure, etc., by measurement of the gamma rays emitted promptly following capture of neutrons by various target nuclei. Located at the base of the reactor, the spectrometer sorts the neutron beams according to their energies in much the same way a prism breaks up light into its component wavelengths or colors. The spectrometer has also yielded much information on radioactive decay schemes.

More recent installations are two cryostats which irradiate materials at $4^{O}K$ or "absolute temperature" ($-269^{O}C$ or $-450^{O}F$), and a third cryostat, a cold neutron facility which uses deuterium oxide as ice. These are used for studies of radiation damage at extremely low temperatures.

CP-5 has also been used for projects such as cloud chamber experiments, flux measurements, neutron diffraction studies, delayed neutron measurements, and shielding experiments for the "Atoms for Peace Program" under the late President D. D. Eisenhower.

Of the nearly 20,000 sample irradiations conducted within CP-5, most have been in support of Argonne research projects, but many have also been requested by universities, hospitals, industrial firms and other research laboratories.

Some of the more interesting samples irradiated over the years have been air, dirt and cellulose for air pollution studies, stone meteorites to help determine the age of the universe, and diamonds, which turn a bluish-green when irradiated. All sorts of electronic components have been irradiated for the Admiral Corporation and even sweeping compounds for General Motors. Paint and hair have been irradiated for crime detection studies by the Chicago Police Department. (The paint chips would be used to trace cars, and irradiated human hair seems to be almost as individual as fingerprints.) Tomato, asparagus and pea seeds were irradiated for the California Packing Corporation and tobacco leaves and cigarette tobacco for the University of Kentucky. USA quarters, algae samples, blood serum, human bone and fingernails have been inserted into the reactor for various studies.

Fuel burnup studies, as well as irradiations of all types of compounds and metals such as einsteinium, gold and ytterbium are always in process. There are also always some autoclaves in the vertical thimbles which contain startup sources for private and AEC reactors.

Rehabilitation

A rehabilitation program is now in progress to update the 14-year-old reactor. Various components will be replaced or modified to meet current standards, codes and practices, thereby providing a medium-power research reactor consistent with the latest in external equipment and design. Primary revisions will be in the instrumentation, ventilation and cooling systems; the heavy-water process piping and equipment will be replaced. This rehabilitation program will not alter the 5-MW power level of the reactor.

After rehabilitation, CP-5 will have a triplicated instrumentation system of the latest design. Three sensors will monitor each of the necessary points in the system, and two out of the three sensors must concurrently detect an abnormal parameter before the reactor will shut down automatically. Thus a breakdown of any one sensor will not cause a reactor shutdown.

A closed-circuit television system will also be installed to monitor the perimeter gates and the building front door from the control room, giving the supervisor in charge increased control over those who enter after Laboratory hours.

The rehabilitation project should be complete in late 1969. By this time, the new systems and equipment will have been tested and the shakedown operations will be completed. Two months later, after criticals and low power operations, CP-5 will again resume continuous operation.

EBWR, THE POWER COMPANY PROTOTYPE

Can electricity be produced economically in nuclear power plants? Is the "boiling" principle for nuclear power reactors feasible? Can the power reactor be safe enough for widespread use by private utility companies?

The Experimental Boiling Water Reactor, the next member of Argonne's reactor family, was constructed in answer to these and many similar questions. The dome-shaped power plants which today dot the nation's landscape attest to the success of the prototype EBWR.

EBWR, the first reactor in the Atomic Energy Commission's civilian power reactor development program, was designed to study and to demonstrate the practicality of direct-boiling power reactors (a reactor which generates steam within the reactor vessel itself). The feasibility and safety of large-scale power plants, using uranium fuel of the lowest possible U^{235} enrichment, were to be illustrated by this reactor built for steady power generation.

The simplicity of the direct-cycle boiling water design, the elimination of heat exchangers, and the inherent safety characteristics of the system gave EBWR a special significance in the development of nuclear power.

The paperwork---design, engineering and related activities---for EBWR was thus begun in March of 1954 by Argonne's scientists and engineers. By May 27, 1955, construction was begun on the first nuclear power system in the United States dedicated solely for experimentation in the generation of electric power.

A small informal ground-breaking ceremony soon developed into an enormous seemingly bottomless hole, as more of the plant is below ground than above. Huge steel plates were lowered into place and the structure began to rise. Only a year and a half later, the project was finished---a neat, new silhouette on Argonne's landscape.

Under the direction of John M. West of Reactor Engineering, Project Manager, EBWR achieved criticality on December 1, 1956. On December 23, it produced its first power in equipment checkout tests. In keeping with the holiday season, the first Christmas tree was lit by nuclear power that Christmas. EBWR reached its rated 20 MW (heat) level on December 28, and the next day generated electricity at its rated power level. Step by step the reactor had worked like a charm and was now ready to be placed "on stream."

February 9, 1957 was EBWR's big day. Dedicated to the peace and prosperity of mankind, it was put "on the line" as the nation's first reactor to produce large-scale daily quantities of useful power. The dedication ceremony was climaxed at 2:30 p.m. when the Laboratory switched from conventional to nuclear power.

After being brought to full power on December 29, 1956, EBWR compiled an impressive record of trouble-free service. During one test, the reactor poured out power for three months without interruption. For this entire period, about half of the Laboratory's electrical power, normally supplied by the Public Service Company of Northern Illinois, was successfully provided by EBWR.

In the first 26 months of operation, EBWR and its generating plant produced 30,981,000 kW hours of electricity, enough to supply the needs of 10,000 average American households for one year. By this time EBWR was certainly helping to map America's route to economical electrical power.

On December 2, 1957, the operating power level was doubled from 20 to 40 MW with no change in the number or arrangement of fuel elements. Two months later, on February 9, 1958, the operating power level was again increased, this time up to 60 MW, with no fuel change. These power increases opened the door to substantial reductions in the cost of producing nuclear power. Further power increase was precluded by the feedwater pumps which were operating at maximum capacity.

At this time a detailed study of EBWR's stability was undertaken to predict the reactor's performance at higher power levels. The study indicated that with some modification of the core structure and pressure vessel internals, and with additional heat-removal equipment, EBWR could operate at or near 100 MW(t). In July of 1959, the reactor plant was shut down for these proposed plant modifications under the direction of Edward A. Wimunc, Project Manager.

The modification of EBWR represented another successful pioneering endeavor at the birthplace of nuclear reactors. In addition to the system changes and additions that were effected, the core was instrumented extensively which entailed development of unique instrumentation techniques. Modifications and testing took about three years and on November 15, 1962, EBWR successfully reached its new goal of 100 MW--five times its original design capacity. The electrical output remained the same; the additional heat generated was intended for space-heating of Laboratory facilities.

This kilowatt level of operation marked the culmination of that experimental program with the reactor. Thus, the reactor was shut down on December 6, 1962, but it was not idle for long.

Much of Commonwealth Edison of Chicago's nuclear plant at Dresden, Illinois, the first privately-owned reactor for the production of electricity, is based on the EBWR design.

Description

EBWR is a direct-cycle boiling, 20 MW (heat) reactor which provides, in the form of 600-psig saturated steam, the energy for generating 5,000 kW of electricity. Using slightly enriched uranium fuel, it is moderated by light water. The size of the plant is small in comparison with most modern power stations, but it has operated with optimum efficiency and economy.

The reactor consists of a steel pressure vessel of 2-3/8 inch wall thickness containing zirconium-clad uranium fuel elements, control rods and light water. The reactor per se is located entirely below ground level.

The core inside the pressure vessel consists of fuel assemblies and control rods fitted into a support and shroud structure which will hold up to 148 fuel assemblies within a five-foot diameter grid. The first core, about four feet in diameter, consisted of 114 assemblies, of which 106 contained slightly enriched uranium and 8 contained normal uranium. An overall enrichment to 1.4% U^{235} was required for the operation with light water. Dummy assemblies were used to fill out the core to the five-foot diameter.

With the "boiling water" design concept, during the nuclear reaction, the fissioning of uranium atoms releases heat which converts part of the water in the core to steam. This steam, at 600 psig, is piped directly to a turbine-generator similar to those used in "conventional" power plants. The spent steam goes to a condenser, after which the water formed is returned to the reactor vessel. Circulation of the cooling water through the core is by natural convection.

This direct connection between the reactor and the turbine eliminates the need for costly, intricate and less efficient heat exchange equipment. The reactor and turbine thus operate at the same pressure.

Operation

All the steam plant as well as the reactor equipment is designed for continuous remote-control operation and is equipped to prevent the escape of radioactive water or contaminated material. This requires an intricate system of instruments, alarm signals and control mechanisms, with all communication elements located in the control room outside the power plant containment shell.

From his station at the control room console panel, the operator can maintain constant vigilance of the meters and signals showing conditions throughout the plant. He can adjust the controls accordingly. For safe, steady operation, many of the variables are equipped with automatic controls. The apparatus in the control room is connected to that in the plant area by about 1200 electrical cables which pass through gas-tight ports in the containment shell.

The reactor is controlled by movement of control rods driven by mechanisms located beneath the reactor. A complicated interlock system requires that 15 conditions be met before the reactor can be started up. Similarly, if the limit set on any one of these conditions is exceeded when the reactor is operating, it will be automatically shut down. When all 15 conditions are in order, the operator has full command of the control rod operation and can control the reactor power within the limits of the safety interlock system.

The unique structure that houses the power plant is a huge welded steel shell, half underground, giving complete protection against the escape of radioactivity to the atmosphere should any part of the system be damaged. This shell can withstand 15 pound/in^2 internal pressure.

The reactor itself is suspended from a huge steel frame and elastically mounted. A massive steel plate and yoke cover the reactor. In the unlikely event that the reactor vessel itself should ever rupture, the steel cover and concrete shields on the sides would direct all fragments downward.

Originally, EBWR was directly managed by Reactor Engineering. Laboratory Research Reactor Operations was called upon to supply only the operating crew. Six operators from CP-5, John Daniel, Russ Morley, Gus Schulke, Bill Treharne, Art Schmidt and Al Pierce, made up the operating staff under Robert Campbell, first Facility Supervisor. One or two of these reactor operators were put on each shift along with the Reactor Engineering personnel.

Soon, however, complete management of the reactor was turned over to the LRRO Division. Russ Morley became the Coordinator (this title has since been changed to the Assistant to the Facility Supervisor).

EBWR's Role in the Plutonium Program

In anticipation of EBWR's release from the power reactor development program, the Division of Reactor Development in early 1962 requested that Argonne participate in the Plutonium Recycle Program with particular emphasis on work appropriate for the EBWR facility.

Thus EBWR completed one experimental program only to be readied for another. EBWR was loaded with a combination of plutonium and uranium nuclear fuel. With its new core, EBWR was expected to provide experience and data to help develop the potentialities of plutonium, the nuclear fuel of the future. This information was essential to the design of future plutonium-fueled atomic power plants and to plans for modifying existing reactors to run on plutonium. The Reactor Physics Division was responsible for this program.

For this experimental program, the EBWR fuel core consisted of a central zone of 36 zircaloy-2 clad assemblies, containing 1.5% plutonium and 98.5% uranium. These central assemblies contained about 31 pounds of plutonium. The outer portion of the core consisted of 111 zircaloy-clad uranium dioxide assemblies, of which 60 were enriched with 6% U^{235}.

The first self-sustaining nuclear chain reaction with the new fuel in EBWR was achieved on September 22, 1965. During the following year, an extensive series of physics experiments was conducted at near zero-power levels. Low-power operation at higher system temperatures and pressures began on October 11, 1966. The generation of electricity began the next day, October 12. The reactor reached a power level of 42,000 kW of heat on November 11, 1966.

In this new role, the reactor provided scientists and engineers an opportunity to study the effects of the burnup of plutonium-239, the isotope composing the largest portion of the plutonium in the fuel, and the effects of the accompanying creation of new fissionable isotopes. At the same time, EBWR provided steam to drive the 5,000-kW generator feeding electricity to the Argonne power lines.

EBWR was closed down during the summer of 1967 for its role in the Plutonium Recycle Program had ended. EBWR had proved successful in every one of its endeavors. EBWR still stands--and perhaps in the future it may again demonstrate its excellence in another capacity.

TODAY'S REACTOR OPERATIONS DIVISION EVOLVES

On June 1, 1957, shortly after initial operation of the power reactor EBWR, the Laboratory Research Reactor Operations Division was retitled the Reactor Operations Division--the name which still remains. At this time, the Division was placed under the jurisdiction of the Technical Services Division, so it ceased to be a scientific division in its own right.

The organization which existed at that time, still under the direction of Dr. W. H. McCorkle, was very similar to our present system.

On July 1, 1961, Fredrick H. Martens took over as Division Manager of the RO Division. Martens had previously worked ten years in Reactor Engineering and a year and a half in the Technical Services Manager's Office.

The Atomic Energy Commission at Ames, Iowa, was constructing a research reactor, a carbon copy of CP-5, and Dr. McCorkle left to direct the project. He originally planned to split his time between Ames and Argonne until JANUS, a new biology reactor in the planning stages, was completed. Dr. McCorkle was a Project Engineer on JANUS.

However, shortly after he transferred to Ames, McCorkle was injured quite seriously in an automobile accident. He was no longer able to commute between the two laboratories and was forced to terminate his work on JANUS. Thus the JANUS project was handled by the RO Division under Fredrick Martens.

THE JUGGERNAUT REACTOR

JUGGERNAUT, a small, but highly versatile, nuclear research reactor, joined Argonne's impressive reactor force on January 11, 1962. Built to supplement CP-5, JUGGERNAUT serves as a general purpose reactor, permitting a wide range of experiments by Argonne's scientists and engineers. Ever since its completion, CP-5 had been swamped by experimenters. Since scheduling of all the desired experiments had been impossible, JUGGERNAUT came into being to relieve some of CP-5's load by providing additional facilities for the expanding nuclear research programs. Despite its small core size, this compact research tool has proved to be an economical and dependable source of neutrons for nuclear research.

The name "Juggernaut" is quite formidable, even for a nuclear reactor. Of Hindu origin, it means literally "lord of the world; a massive inexorable object or force which crushes whatever is in its path."

The JUGGERNAUT is housed in a prefabricated metal structure. A one-story reinforced concrete, brick-veneered structure, designed by the architect-engineering firm of Skidmore, Owings, and Merrill of Chicago, is attached to the building and contains the control room, offices and supporting services. The reactor itself was designed and built by Argonne.

JUGGERNAUT's design is based on the design of the Argonaut (ARGOnne's Nuclear Assembly for University Training). The Argonauts, in Greek mythology, were the heroes who sailed with Jason on the Argo in quest of the Golden Fleece. Designed primarily for instruction in reactor technology, the Argonaut reactor is "an adventurer engaged in a quest" for nuclear knowledge. Like this predecessor, JUGGERNAUT serves as an educational as well as a research tool. College and university students from every part of the world have used it to pursue the complex problems of nuclear science. JUGGERNAUT, however, operating at 250 thermal kilowatts, has 25 times the power of its predecessor.

On June 6, 1962, JUGGERNAUT ended its period of development and testing and began continuous operation under the jurisdiction of Fred Martens, Division Manager of Reactor Operations. John Beidelman was its first Reactor Facility Supervisor and Fred Cokeing was, and still is, the Assistant to the Facility Supervisor.

Description

The JUGGERNAUT Research Reactor is an enriched-uranium, light-water-moderated reactor with an annular core reactor. It is operated during the day by three operators, although for its first three years it was operated around the clock, five days a week.

The reactor shielding is octagonal in shape. Twenty assemblies of aluminum-clad uranium fuel plates in a tank of demineralized water form the nuclear heart of the reactor. Ordinary light water serves as a moderator and a coolant. Surrounding the core is a layer of graphite which reflects escaping neutrons back into the uranium fuel. Some of this graphite dates back to that historic "pile," CP-1.

JUGGERNAUT has seven safety and control mechanisms of neutron-absorbing boron in stainless steel which are of the "window shade" type. They are slowly drawn up to start the reactor, and quickly released to stop the fission chain reaction. A cadmium tubular regulating rod is used for fine control.

An outstanding feature of the reactor's design is the fuel arrangement. The fuel is contained in an annular tank surrounding an internal graphite thermal column, a vertical, cylindrical region in which there is an abundant supply of thermal neutrons. This graphite chamber in the center of the core provides a high-intensity neutron area for sample irradiations.

Experimentation

A second design feature permits great versatility in the arrangement of experimental equipment. Sixty percent of the reactor shielding consists of large movable concrete blocks. This permits large pieces of experimental equipment to be exposed to a large, intense source of neutrons. A crane simply removes the concrete shielding blocks, the equipment is installed, and the blocks are rearranged around the experimental equipment.

Other openings, which permit insertion of samples for neutron bombardment or which allow the emission of neutrons, include two thermal columns in the side of the reactor, four horizontal beam holes with gates to permit neutrons to escape into measuring devices, and ten vertical irradiation holes. In all, 22 facilities of various kinds give access to the heart of the reactor for nuclear research. Research has been conducted to gain basic information on the slowing down behavior of fast neutrons, neutron radiography, fission counting, the comparison of fission rates, the measuring of material cross sections, the diffusion rates of uranium, and other related types of experimentation.

One of the most noteworthy JUGGERNAUT experiments was conducted by Harold Berger (MET) on neutron radiography. This experiment led to the development of an entirely new method of "seeing through" opaque objects. Unlike X-rays, neutron radiographs can clearly distinguish between objects of high intensity, such as lead and uranium. This work was selected by Industrial Research Magazine as one of 100 most significant technical achievements of 1965.

On November 30, 1966, this small versatile reactor recorded an impressive 2,000,000 kW hours of operation, without a major shutdown. After seven years, it is still operating with its original fuel elements, although a refueling is scheduled for this year.

TWO-FACED JANUS

On August 8, 1964, Argonne's newest reactor JANUS went critical. A reactor with two radiation faces, JANUS derives its name from the ancient Roman god of beginnings represented with two faces looking in opposite directions. The month of January was named after this god. A combined effort of the Biology and Reactor Operations Divisions, JANUS is a biological reactor for neutron irradiation studies. It was erected adjacent to the biology building rather than in the reactor complex to make the facilities as convenient as possible for the biologists.

Argonne's biologists and medical researchers are conducting an extended research program on the biological and genetic effects of irradiations on small animals. This research program is directed largely toward evaluations of the effects of acute and chronic exposures to fission neutrons.

In chronic exposures, the dosage rates are considered to be comparable with those experienced by personnel associated with day-by-day operation and use of nuclear research reactors and nuclear power plants. The dosage rates for studies of acute radiation exposure are expected to be no more than from 10^4 to 10^5 higher than for chronic exposures.

Conducting large and long term studies of chronic exposure, while concurrently studying acute exposure, requires that there be two irradiation regions where chronic and acute exposure studies may be simultaneously performed without influencing each other.

JANUS is uniquely designed to study the effects of high and low intensities of neutron radiation on animals. Its two radiation faces simultaneously deliver different neutron intensities to two rooms for low-level and high-level irradiations. Whole-lifetime "chronic" effects as well as "acute" high-dose effects are investigated. Research is centered essentially on three problems: a) differences in time and cause of death following neutron and gamma irradiation, b) deviations in additivity of neutron and gamma radiation in causing death, and c) differences in recovery rates following neutron and gamma irradiation.

Description

JANUS is a heterogeneous, light-water-moderated reactor of the tank type. The core is composed of 19 tubular fuel assemblies similar to those in CP-5 and containing enriched uranium. Ordinary water serves as both moderator and coolant. The uranium-bearing portion of this core is about 26" long. The core, installed in an aluminum tank 4' in diameter and 7' high, is situated slightly off center to provide the different neutron intensities in the two rooms. The vertical axis of the core and the reactor tank axis are parallel, but are slightly offset.

JANUS is normally operated at a power level of 200 kW. It has seven cadmium control rods. Six of these, symmetrically arranged around the center of the core, serve as shim-safety rods. The seventh, arranged for continuous manual or automatic adjustment, is the regulating rod.

The irradiation room for high doses (1 rad/min to 50 rads/min) is approximately 12' long, 16' wide and 10' high. A convex radiation face allows neutrons to escape from the reactor. This opening, 3' high and 6-1/2' wide, is about 5 feet from the center of the fuel core. This room can accommodate hundreds of mice for a single experiment.

Directly on the opposite side of the reactor is the radiation room for low doses (0.1 to 100 rads/week). This room is approximately 23' long, 23' wide and 11' high and can accommodate thousands of mice for one experiment. The radiation face opening in this room is 3' high and 10-1/2' wide and approximately 7 feet from the center of the fuel core.

JANUS has other special features unique in reactor design. Movable converter plates can be placed over each face of the reactor to produce fast neutrons. Movable neutron shutters can be placed over the irradiation faces thus allowing experimenters or operators to be present in the irradiation rooms during reactor operation. It also has lead shielding in front of each face to minimize gamma radiation and a neutron attenuator on the low-dose side. A pneumatic rabbit and a hole in the graphite thermal column on the high-dose face are available for special irradiations.

JANUS has no definite operating schedule or level of operation, but is run on an experimenter request basis by three reactor operators. The maximum level of operation is 200 kW.

JANUS is currently undergoing modifications to increase its effectiveness as a biological research tool.

TRAINING PROGRAM FOR OPERATORS

All training for operation of the reactors was on-the-job in the early years of the organization. However, as the reactors became more and more sophisticated, more and more specialized training was required.

With the completion of EBWR in early 1957, Edward A. Wimunc, Project Engineer, formed a special training program for the operators of EBWR. The chief reactor operators were assigned the responsibility of specific areas or systems, which they studied and mastered. These chief operators were then responsible for passing on this information to the rest of the operators. Actual training sessions were held and qualification tests were given. Still there was no set formal training program to encompass the operators of all the reactors.

Around 1962, there was a great influx of new reactor operators. CP-5, EBWR, and JUGGERNAUT were all operating and JANUS was nearing completion. A real need for a training program existed and was recognized. Thus Fred Martens, RO Division Manager, appointed Rodney Davison as Training Coordinator. His duties entailed the organization of a formal training program and the coordination of the training activities.

The training program had two distinct parts: a) a Basic Information Course, consisting of lectures by various RO staff members, and b) a Reactor Systems Course, handled by the chief reactor operators. Following these basic courses, a Refresher Training Program was constantly in effect to keep the operators up to date on all changes and modifications. The annual qualification examination program was also initiated at that time.

This is the basic program which is in effect today, although it has been greatly expanded and refined. The training aids and training techniques have changed to meet the demands of particular situations and particular people.

To give an idea of the extent of the program, when a new operator enters the scene, no longer does he take over the control room in a couple of days. Instead, he embarks upon an extensive training program to become qualified as a reactor operator. The increased nuclear instrumentation, the complexity of the higher power reactors, and governmental regulations and requirements have necessitated this formalized program.

The qualification procedure involves two stages:

1. When an operator has obtained a general understanding of the reactor and process systems, and is thoroughly familiar with and has passed a test on emergency procedures, he becomes

a Partially Qualified Operator. He can operate the reactor, but only under the direct supervision of a Qualified Reactor Operator.

2. To become fully qualified, the operator must be thoroughly familiar with all aspects of the reactor operations, and must pass written qualification examinations on design and construction features, flow systems, physics, radiation safety, reactor operation and procedures, and instrumentation and reactor control. Only after satisfactorily passing these examinations and an oral review does the new man become a Qualified Reactor Operator.

The Refresher Training Course and the yearly qualification examination keep the operators abreast of latest information and modifications. These written examinations are followed by an oral review by the Facility Manager, Training Coordinator and an operation staff member. The operators complete and pass the examinations to remain qualified reactor operators.

ATOMIC ENERGY COMMISSION'S ROLE

Paperwork, regulations, and restrictions have increased over the years with the advent of increased organization, larger and more complex reactors, and operating experience. Since Argonne's reactors are AEC-owned, the Atomic Energy Commission plays a primary role in the control of the reactors. AEC-owned reactors, termed "8401 reactors," are maintained and operated according to the rules and guidelines set forth in Chapter 8401, "Safety of AEC-Owned Reactors," U.S.A.E.C. Manual.

The three basic points of the AEC policy on reactor safety are:

1. The AEC must assure that reactor facilities are designed, constructed, operated and maintained in a manner that protects government and contractor personnel, government equipment and the general public against exposure to radiation or other potential health and safety hazards.

2. The design, construction, operation and maintenance of AEC reactors must be in accordance with generally uniform standards, guides and codes.

3. The potential hazards associated with any proposed construction, operation, or significant modification of the design or operating conditions of an AEC-owned reactor must be properly analyzed, evaluated and documented prior to any action.

To fulfill these policy objectives, the Atomic Energy Commission has a number of requirements, of which these are a few, which must be followed by its contracting groups.

Prior to construction of a new reactor, a Preliminary Reactor Safety Analysis Report must be submitted to the AEC for review and approval. Prior to initial reactor operation, a Final Reactor Safety Analysis Report is required. Before a reactor can undergo any modification program, an Amendment to the Reactor Safety Analysis Report must be submitted and approved. All of these reports must also be submitted to an Advisory Committee on Reactor Safeguards for review when new or unusual safety questions are involved on a reactor exceeding 10 MW (thermal). Hazards Summary Reports are also required for each installation.

The AEC requests a set of approved "Operating Limits" for each of its reactors and has also issued AEC reactor safety standards, guides and codes to be followed by the contractors. A Reactor Safety Survey is conducted semi-annually by the AEC to assure the application of these AEC guidelines. The AEC submits its survey findings and recommendation to the Laboratory.

ARGONNE ESTABLISHES ADVISORY COMMITTEES

Besides the well-qualified and trained operators and supervisors, thoroughly acquainted with the rules and procedures for startup, operation and shutdown of the reactors, certain groups have been organized which meet periodically to inspect and schedule experiments and to insure safe reactor operation. Organized in the 1950's and early 1960's, these groups are known as Argonne's Internal Advisory Committees. These committees serve to help Reactor Operations fulfill its primary objectives--to run a safe reactor, and, concurrently, to minimize the reactor down time.

Reactor Safety Review Committee

Because of the increasing number of Argonne-operated reactors at this site and in Idaho, and because of an increasing number of reactor and critical experiments, it became necessary to formalize general policies and procedures on reactor operation safety. Thus on April 10, 1957, the Laboratory issued Policy and Practice Guide Statement 57-3 on the Safety Review of Reactor Experiments, and a Reactor Safety Review Committee was established to assist in the implementation of these policies. The main purpose of the committee has been to advise and make recommendations to the Lab Director on safety aspects pertaining to the operation of Argonne's reactors.

The policies set forth in statement 57-3 were:

1. All requests for permission to operate new reactor experiments or for approval to modify existing experiments should be submitted to the Lab Director with copies to the Laboratory's Reactor Safety Review Committee (RSRC).

2. The operating manuals for all reactor facilities must be reviewed and updated annually, with revisions being made more often if changes affecting safety aspects are involved. Also, prior to any startup of a facility, preliminary manuals must be furnished to the Lab Director and RSRC, and final manuals to the operating personnel.

3. Only authorized personnel will be permitted at the controls of a nuclear reactor. This authorization involves a notation from the Division Manager to the Laboratory Director stating that an individual is qualified to operate a particular machine. The operator's pertinent training and experience are included.

4. The Hazards Evaluation Reports, prepared for transmittal to the AEC, must be reviewed first by RSRC. These reports include Initial Hazards Memos (IHM), Preliminary Hazards Reports (PHR), and Hazards Summary Reports (HSR).

The Reactor Safety Review Committee is Lab-wide in scope, its members appointed by the Laboratory Director from several scientific divisions. In general, the Committee maintains a continuing review of all operating reactors. Semi-annual, on-the-site inspections are held to note all changes in reactor equipment and operating procedures. The Committee considers the special nuclear hazards involved in proposed reactors or nuclear multiplication experiments, and devotes special attention to reactor hazards primarily affecting Laboratory personnel.

Users' Committee, CP-5

A Users' Committee was established by Technical Services for the CP-5 research reactor on October 20, 1958. The first official meeting was held on November 13, 1958, with Dr. G. R. Ringo (PHY) as chairman. The committee acts to advise the Division Manager of the experimenters' needs and to inform experimenters of existing and planned activities at the reactor.

The committee is composed of one representative and one alternate from each of the major using divisions. The members are selected from those who actually carry out research on the reactor as their major activity. The Reactor Operations Division is also represented on this committee.

The duties of the committee include:

1. Receiving from the RO Division Manager information on experiments, reactor operating schedules and anything affecting the operations of the experiments at the reactor.

2. Reviewing proposals for major experiments, irradiations and associated apparatus at the reactor; advising the RO Division Manager with respect to the probable effect of proposed activities on experiments at the reactor; scheduling work requiring abnormal operation of the reactor.

3. Recommending to the RO Division Manager procedures and practices affecting the use of the reactor by experiments.

After completion of JUGGERNAUT, the committee was expanded to include CP-5 and JUGGERNAUT users and was retitled the Reactor Users' Committee.

Reactor Facility Review Committee

In 1958, CP-5 was being modified to increase the power level of operation. The resulting increased neutron and gamma fluxes in the irradiation facilities thus required special attention to the design of all the experimental assemblies to be placed in these facilities. Therefore, Dr. W. H. McCorkle, RO Division Director, established the Reactor Facility Review Committee on January 20, 1959.

The committee, whose aim is to expedite the experimental program at CP-5, is composed entirely of Reactor Operations personnel, headed by the Division Manager. No new or unusual experimental devices can be inserted in the reactor facilities without the approval of the Reactor Facility Review Committee.

This group serves to examine and evaluate proposed experimental installations for: a) engineering quality and compatibility with reactor structure and design; b) scheduling and effects on operational procedures, maintenance, etc., and c) compliance with AEC rules and regulations, reactor safety, radiation hazards, etc.

The committee was initially composed of three members: Herbert C. Stevens, Associate Engineer, who helped experimenters on the design of their equipment for use on CP-5; Joseph I. McMillen, CP-5 Reactor Supervisor, who advised experimenters concerning approval to perform experiments and assisted them in arranging schedules for the experiments; and Dr. Willard H. McCorkle, Division Director, who had final approval of experimentations and irradiations at CP-5.

Criticality Hazards Control Committee

By 1960 an immense amount of fissionable material was being used at the Laboratory. The Laboratory felt a formalized policy was necessary pertaining to the safe handling of such materials in order to guard against criticality hazards. A Policy and Practice Guide Statement (Number 60-3) on Criticality Hazards Control was therefore issued on September 8, 1960.

Since it is essential that anyone handling fissionable materials be constantly aware of the possible criticality hazards involved, it is the policy of the Laboratory that adequate written procedures, approved by the Laboratory Director, exist to guard against the accidental criticality of fissionable materials. The following procedures are required:

1. A written statement for each division charged with a total of 300 grams or more of Pu^{239}, U^{233} or U^{235} is required, which details the measures necessary to prevent accidental criticality from the fabrication, processing, storing, transfer or other handling of fissionable materials.

2. Each division must appoint one or more staff members to serve as Criticality Hazard Control Representatives. These representatives, who prepare the division's written statement, have the authority to stop or prohibit any operation involving fissionable materials, if not safe from a criticality standpoint.

3. A Laboratory Criticality Hazards Control Committee, an advisory committee of qualified staff members appointed by the Lab Director, reviews all matters pertaining to possible criticality hazards and recommends appropriate action to the Lab Director. The committee reviews the written statements annually and conducts physical inspections as necessary to determine the adequacy of, and the compliance with, the approved statements.

TECHNICAL SUPPORT GROUPS

Prior to the emergence of a Reactor Operations Technical Section, Reactor Engineering or Central Shops handled the technical assistance for the experimenters and reactor operators. For example, when an experimenter needed some special equipment to fit the reactor, he went to a shop engineer with his specifications. These engineers were not familiar with reactors. Often two or more men worked on the same project and the requests were not fully understood or totally fulfilled. More often than not the equipment did not fit the reactor nor function as desired, and modifications were required. Incidents of this type made it obvious that an internal technical staff was essential to assume these tasks.

Although the Technical Section per se was not formally organized until 1962, in reality it originated in 1949 when Herbert C. Stevens

(PO) was hired as the first staff engineer in the Pile Operations Group at Site A.

Stevens remained the only staff technical assistant, although he was aided by technicians, until 1953 when Loyal Lapham, a former student of Dr. McCorkle, was hired as a physicist. Two years later, John Folkrod joined the staff as a second engineer and Lapham left the Laboratory. Folkrod and Stevens then handled the technical support for the group.

Around 1958, after the completion of EBWR, the work load had greatly increased and a number of new people were hired into the technical group including John Condelos, Dr. James Talboy (RO), Herb Naylor and draftsmen Harry Cern, Jim Moudry and Ron Smith (all RO).

The Technical Section, under the leadership of Herb Stevens, was formed in 1962. The primary functions of the section were to aid experimenters in setting up experimental equipment and to maintain the reactors in operating order (could be called development engineering and maintenance repair engineering). Although not specifically categorized at first, the section was composed primarily of three subsections with one or two staff members per section. The subsections were engineering development, reactor engineering, and physics, instrumentation and control. The latter group was soon separated into two sections--physics, and control engineering and instrumentation (CE&I). The Technical Section also encompassed the drafting group and the cave at CP-5.

Herb Stevens was assigned to the AARR project to provide operational input from the Reactor Operations Division in 1964. He was replaced as head of the Technical Section by Peter J. Vogelberger, Jr. Under Vogelberger the section underwent a reorganization. The Physics group under Dr. Talboy split away from the group, reporting directly to the Division Manager.

The remaining Technical Section was comprised of two subsections: Electrical Engineering, under Gerry Matthews (RO), which contained the drafting group and the instrumentation technicians; and Mechanical Engineering, under Tom Banfield (RO), made up of the mechanical technicians. This organization existed until Vogelberger's departure in June of 1965. Matthews then became head of the Technical Section, while still heading the electrical engineering group.

In the fall of 1966, the Technical Section title was dropped, being replaced by the name Engineering Section (still under the jurisdiction of Gerry Matthews). This organization, which exists today, is composed of all the engineers and draftsmen. The technical support groups, which are a part of the CP-5 organization, are offshoots of the former Technical Section.

Today's Engineering Section provides engineering and drafting services to assist in maintenance procedures and in keeping the reactors current. It ensures that all reactor systems, new designs, modifications, tests and experiments are designed and built such that they meet all Laboratory and AEC requirements.

The function of the Physics Section is to provide technical support for the Division's operating sections and to provide information of value to reactor users. The section develops techniques for and measures reactor parameters such as thermal neutron flux distributions, control rod reactivity suppression capabilities, radiation heating effects in experimenter's apparatus and irradiation capsules, temperature and void coefficients of reactivity and time-dependent neutron absorber concentrations.

WIMUNC BECOMES DIVISION MANAGER

Fredrick Martens, now Coordinator of Nuclear Safety in the Laboratory Director's Office, left the Reactor Operations Division in April 1966 to return to research activities. He was replaced as Division Manager by Edward A. Wimunc, a veteran reactor engineer.

Wimunc, an Argonne old-timer long associated with its reactor programs, joined the University of Chicago's "Met Lab" in 1944. In 1950 he became a member of the Reactor Engineering Division, where he served until becoming Reactor Operations Division Manager.

Associated with numerous important reactor programs over the years, Wimunc was Project Manager during the conversion and operation of EBWR from 20 to 100 megawatts. Very few men can match his 20-plus years of experience in reactor technology.

Much has transpired since Dr. Enrico Fermi and his associates first dreamed of and produced a nuclear chain reaction. Few fields of endeavor are as new or moving as quickly as the nuclear field.

As we have hoped to illustrate, Argonne National Laboratory and the Reactor Operations Division have served as leaders in the establishment and advancement of the nuclear power industry.

No other reactor operating group can match our experience nor boast of such a heritage. We span the entire existence of the nuclear era. Most of the original "pile operators" are still members of the Reactor Operations Division. These members have made such a document possible by contributing authentic, first-hand information about reactor operations in their infancy.

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