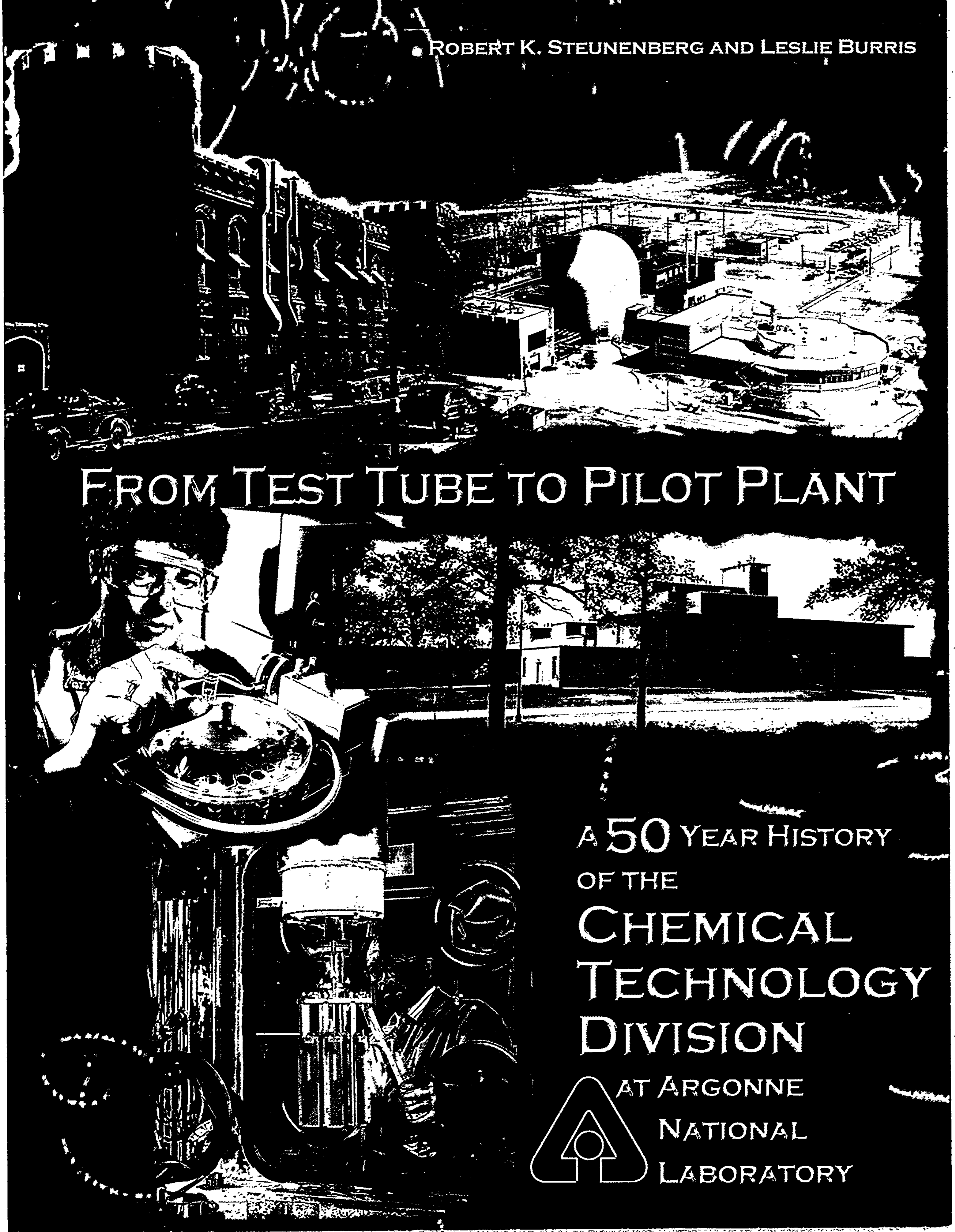

Robert K. Steunenberg and Leslie Burris

From Test Tube to Pilot Plant

A 50 Year History of the Chemical Technology Division at Argonne National Laboratory

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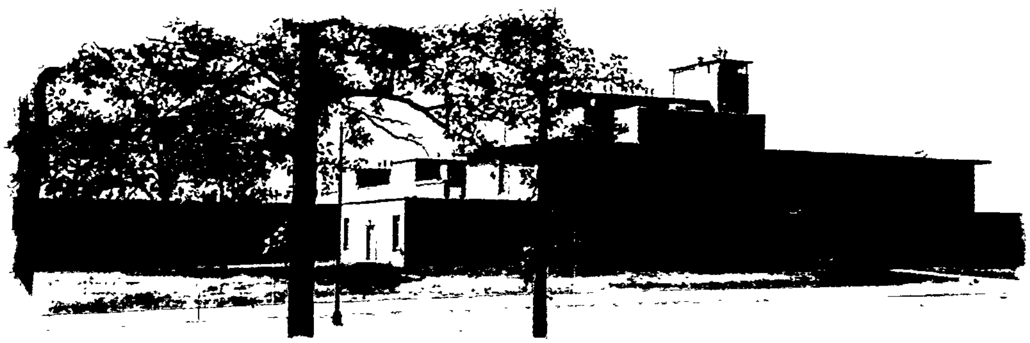

A 50 Year History of the Chemical Technology Division at Argonne National Laboratory

Building 205 at Argonne National Laboratory.

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Contents

Foreword

The idea of writing a history of the Chemical Technology Division was proposed in 1994 by Dr. James Battles, who was the Division Director at the time. About the only guidance Jim provided was that he had in mind neither an extended technical report, nor a "puff piece" extolling the scientific and engineering prowess of the organization. The people in the Division do, in fact, have reason to take pride in the many scientific and technological contributions they have made and the excellence of the work. But the intent of this document is to tell the story of how the Division originated and to give the reader a general idea of what research and development work has been done, why and how it was done, and who did it.

There are several reasons why we created this document. A number of the Divisional staff have expressed concern about losing some of the technical knowledge of the old timers who are retiring, particularly the kind of lore or "know-how" that is not normally documented in technical reports. Dr. Battles expressed the thought that newer members of the Division might gain a useful perspective on how the Division came to be what it is now. Others have expressed curiosity as to why various programs were started, redirected, or terminated. Even those people who have worked in the Division for many years often tended to focus on their own research and were not always fully aware of what others were doing.

When we started writing this volume, it was immediately obvious that detailed literature references would be impractical. They would run into tens of thousands. By the same token, descriptions of the technical programs are very abbreviated. Summary reports alone of the Division's work have averaged several hundred pages per year for 50 years; we have attempted to compress the information in these summary reports to considerably less than 5% of the original volume, and probably did so unintentionally in a somewhat uneven manner. We beg forgiveness from any individuals who might feel that their contributions have been slighted. Where there are such cases, it was certainly not out of malice.

This is not intended to be a reference book, nor have we attempted to generate a subject index. We have, however, included a rather detailed table of contents as an appendix. It happens occasionally that somebody has a vague recollection of work done many years earlier which might be germane to a current problem but cannot remember exactly what it was, who did it, or when it was done. There may be times when the detailed contents table could be helpful in tracking down such a source. Also included as an appendix is a list of acronyms with their definitions.

At the start of each chapter, we have included some discussions of national and world affairs that may seem extraneous, but they have had a major influence on the nature of the Division's programs as public perceptions changed and political wind shifts occurred over the years. They also serve as sort of a time line that might help the reader relate the Division's work to the outside world. For example, nuclear power was a popular idea in the 1950s and 1960s, and the national laboratories were mandated by Congress to promote the concept under the Eisenhower "Atoms for Peace" program. Much of the Division's work at that time involved nuclear fuel reprocessing and fast breeder reactors, and our discussions probably reflect a pro-nuclear attitude during that period. During the 1970s, however, it was becoming clear that nuclear power was not going to solve the nation's near-term energy problems, and much of the Division's effort was shifted toward alternative sources (solar and fusion power), improved utilization of existing sources (coal), and conservation (the battery programs). Most of the Division's applied programs at present are directed toward environmental concerns, a major one being the handling and disposal of plutonium and nuclear wastes.

Joe Harmon, head of the Division's Technical Editing Group, put a difficult question to us: "Who would be interested in reading a book of this kind and at what technical level will it be pitched?" The technical level, we believe, is one at which nearly everything would be comprehensible to the average chemist or chemical engineer. Although some of the descriptions of the technical programs include equations, phase diagrams, and jargon that might not be understood by a non-technical reader, much of the material is either non-technical or descriptive. We felt that some technical detail was necessary to illustrate the depth and scope of the work. Our suggestion to the non-technical reader would be to skip through the technical sections lightly and just try to absorb the general drift of what the programs were about. This is not a textbook and there is no exam. We would expect most of the readers to be present and former staff members of the Division, some of the administrative and management personnel, technicians and secretaries, some family members, a few people from other ANL divisions or outside organizations such as universities and contractors who worked on the programs. Some students contemplating a scientific or engineering career might be interested in the type of work that scientists and engineers do in a typical research and development organization.

We have attempted to associate names of investigators with the various programs insofar as possible, but found it to be a difficult task, so there may be omissions or errors. For those, we apologize. A name index is included at the back, where names of non-ANL personnel are italicized.

Finally, we wish to express our deep appreciation to the many individuals who helped us create this volume. Joe Harmon's advice, encouragement, and editing were invaluable. He also contributed a major effort in the production of the final document, as did Maria Contos. Dr. Stephen Lawroski, in particular, provided much oral history, as well as many technical details about the early days of the Division. Dr. Martin Steindler also deserves acknowledgment for his careful review of the entire manuscript and many thoughtful suggestions. Others who deserve special thanks for their help include Jim Battles, George Bernstein, Milt Blander, Ron Breyne, Herb Brown, Loretta Cescato, Sharon Clark, Dennis Dees, Pat Finn, Al Fischer, Steve Gabelnick, Helen Hill, Carl Johnson, Jerry Johnson, Irv Johnson, Tom Kaun, Jim Laidler, Ralph Leonard, Dick Malecha, Vic Maroni, Bill Miller, Leo Morrissey, Jan Muller, Sofia Napora, Paul Nelson, Al Panek, Dean Pierce, Jerry Rathke, Roberta Riel, Laury Ross, Wally Seefeldt, Chuck Seils, Mike Thackeray, Ziggy Tomczuk, and George Vandegrift.

Also contributing to production of the final document were Jane Andrew, Judith Carr, Mary Ann Forys, and Barbara Salbego.

Bob Steunenberg
Les Burris

1940-1950: THE BEGINNING

1940-1950

(top) West Stands at Stagg Field, University of Chicago—site of world's first nuclear reactor and, later, first research on nuclear fuel processing by the ANL Chemical Engineering Division.

(bottom) Walter Zinn (left), first ANL Laboratory Director, and Stephen Lawroski (right), first Director of the Chemical Engineering Division.

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1940-1950: The Beginning

The Chemical Engineering Division (CEN), now renamed the Chemical Technology Division (CMT), at Argonne National Laboratory (ANL), was formed officially in February 1948. Its roots extend well back into the Manhattan Project, however, where it evolved from a group in the Chemistry Division of the Metallurgical Laboratory at the University of Chicago and became a separate division. A brief review of the Manhattan Project, the Atomic Energy Commission, and the Met Lab should prove helpful in understanding the various events that led to the formation of the Division and shaped its future role as a research and development organization.

THE MANHATTAN PROJECT

It is generally accepted that the atomic age began in Berlin with the discovery by Otto Hahn and Fritz Strassman in 1938 that uranium can undergo nuclear fission. Earlier workers had achieved fission by bombarding uranium with neutrons, but did not recognize it as such because they mistook the fission product, barium, for actinium. Hahn established clearly that the product was barium by separating and identifying its decay product, lanthanum. The thinking at that time was that neutrons might be captured or that they might knock small chips off the nucleus, but gross fissioning of the nucleus into large fragments was not believed to be possible. Hahn realized that such fissioning was the only explanation for the barium, but he was reluctant to publicize such a radical result without some theoretical backup. He informed Lise Meitner, a highly competent theoretical physicist, of his results. Meitner agreed that the barium could be explained only by fission but was troubled as to how it could occur. She and her nephew, Otto Frisch, also an excellent physicist, after much speculation and agonizing, came up with a liquid drop model. According to this model, the uranium nucleus assumes a sort of dumbbell shape in which the binding forces arrange themselves in such a way that fission can take place. Still somewhat nervous about their finding, Frisch approached the eminent Danish physicist, Niels Bohr, who grasped the concept immediately with much enthusiasm.

Bohr sailed for the U.S. shortly thereafter, and upon his arrival announced the discovery on January 16, 1939, at the Princeton Monday Evening Journal Club, a weekly gathering of Princeton physicists. Almost immediately, related work emerged nearly everywhere. At Columbia University, Enrico Fermi, and Leo Szilard measured the absorption of neutrons by uranium, and Bohr and John Wheeler at Princeton performed a classical analysis of uranium fission. Frederick Joliot-Curie in France confirmed the theoretical model experimentally and attempted to produce a chain reaction. Rudolf Peierls in England determined the critical mass for a chain reaction. This burst of activity over a period of only a year or two led to a high confidence level that a fission chain reaction in uranium was possible. This discovery also led to a great deal of speculation about the possibility of a nuclear weapon, which alarmed many of the scientists who were involved in the work. The totalitarian regimes in Europe had created conditions that caused many of their leading nuclear scientists to flee to the U.S., which assured its future preeminence in the field of nuclear research. But the concerns of the scientists over potential nuclear weapons fell largely on deaf ears in the U.S. Government administration until Szilard, Eugene Wigner, and Edward Teller prevailed upon Albert Einstein to write his famous letter to President Franklin Roosevelt on August 2, 1939.

Once the administration realized the significance of potential nuclear weapons, it reacted as governments usually do—it formed a committee to study the problem. At Roosevelt's request, the National Academy of Sciences (NAS) appointed an Advisory Committee on Uranium (ACU), which was chaired by Lyman Briggs, the director of the National Bureau of Standards. Its mission was to coordinate fission research and to evaluate the possibility of developing nuclear weapons. The committee acted slowly and was relatively ineffective. The increasing intensity of the war in Europe in 1940, however, brought about an ever more rapid mobilization of scientific, as well as military resources in the U.S., along with a strong sense of urgency. A new organization, the National Defense Research Council (NDRC), was formed and placed under the leadership of the director of the Carnegie Institute, Vannevar Bush, who was a well known and respected individual in the power circles of Washington at the time. The ACU was reorganized and placed under NDRC, but it still remained indecisive. At this juncture, three Nobel laureates, Harold Urey, Ernest Lawrence, and Arthur Compton, who were members of a NAS review committee, expressed their impatience with the lack of action, causing Bush to superimpose on NDRC a more powerful agency, the Office of Scientific Research and Development (OSRD). This office was given jurisdiction over all war-related research and development. James Conant, president of Harvard and a well-known organic chemist, replaced Bush as the chairman of NDRC and became his deputy at OSRD. Urey, Lawrence, and Compton provided the leadership for a reorganized uranium committee known as the S-1 Section of OSRD.

The U.S. declaration of war in December 1941, plus various bits and pieces of intelligence emanating from Europe that Germany was most likely attempting to develop a nuclear weapon, finally galvanized the American effort into a strong course of action. The S-1 Section placed Compton in charge of the theoretical and experimental studies of fission and nuclear weapons design. Compton wasted no time in recruiting the necessary physicists, chemists, engineers, and other personnel, mostly from universities and industrial research and development laboratories, and organizing them into an entity bearing the code name "Metallurgical Laboratory" or "Met Lab." There was much discussion as to where the new lab should be located. Cases were made for Columbia, Princeton, Berkeley, Cleveland, and Chicago. Nobody wanted to move. Compton made a unilateral decision that it would be Chicago. His arguments were that (1) the University of Chicago was receptive to the idea, (2) Chicago was conveniently located for travel to other sites, and (3) more scientists were available to staff the operation than on the coasts where faculties and graduate students had been drained for other war work. Between March and June 1942, the staff at the Met Lab increased from 25 to 1,250. Much of the experimental program was conducted in space under the West Stands of Stagg Field at the University of Chicago, a rather forbidding fortress-like structure. The University of Chicago Maroons, a football team once coached by the legendary Amos Alonzo Stagg and known as the "Monsters of the Midway," had suffered a series of embarrassing defeats, as had the U. of C. baseball and basketball teams, so they had withdrawn from the Big Ten.

The first mission of the Met Lab was to determine the feasibility of a uranium chain reaction, and this effort was placed under the very able leadership of Enrico Fermi, who was widely accepted as the leading authority in the group. In addition to his excellent theoretical understanding of the subject, he seemed to have an uncanny intuitive feeling for the fission process. Under Fermi's direction, slugs of natural uranium oxide, and later, uranium metal, were placed in blocks of graphite moderator, which were assembled into a stack or "pile" in a squash court under the West Stands. This pile became known as CP-1 (Chicago Pile No. 1). Criticality was achieved on December 2, 1942, at the stage that Fermi had predicted. Compton, at the Met Lab, called Conant at Harvard and told him "The Italian navigator has landed in the New World." Conant asked, "How were the natives?" Compton replied, "Very friendly." This is probably one of the most widely quoted telephone conversations in history, second only to the original one between Alexander Graham Bell and Thomas Watson.

Even before the success of CP-1, it was recognized that a massive national effort would be needed to develop a nuclear bomb on a timely schedule. This effort, which became known as the "Manhattan Project" (officially the Manhattan Engineer District), was initiated in August 1942. Because of the huge size and complexity of the undertaking, it was assigned to the U.S. Army Corps of Engineers, and Brigadier General Leslie Groves became the commanding officer on September 23, 1942. Groves, although not a universally popular individual, to put it mildly, was a highly effective manager who pushed the Manhattan Project forward at a rapid pace.

During the earlier studies of uranium, Arthur Dempster at the University of Chicago had shown that natural uranium, which is predominantly U-238, also contains a small amount of a second isotope, U-235. Alfred Neir, a postdoctoral student at Harvard, then quantified the U-238/U-235 ratio as 139:1. Bohr came up with a theoretical explanation for the fissioning of U-235 by slow, as well as fast neutrons. Leo Szilard and Walter Zinn at Columbia found that two neutrons were produced by the fissioning of a U-235 atom, and somewhat higher values were obtained later by other investigators, showing that a self-sustaining chain reaction was possible.

While these uranium fission studies were still in progress, a new chemical element, plutonium, was discovered in 1940 at the University of California, Berkeley, by Glenn Seaborg and his colleagues, who produced minute amounts of Pu-238 by bombarding uranium with deuterons in their 60-inch cyclotron. Ensuing work showed that Pu-239 was formed readily by slow neutron capture in U-238:

$$ {}_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239} \rightarrow {}_{1}e^{0} $$
$$ + {}_{93}Np^{239} \rightarrow {}_{1}e^{0} + {}_{94}Pu^{239} $$

The Pu-239 isotope was then found to be even more readily fissionable by neutrons than U-235, so it also became a likely candidate for a nuclear bomb. Furthermore, plutonium, being a different chemical element, could be separated from its parent uranium by a chemical process, which, in principle, is simpler than an isotopic separation. This potential advantage of using Pu-239, however, carried with it the problems associated with its production on a scale sufficient to produce nuclear weapons. A decision was made to pursue both the uranium and the plutonium options for nuclear weapons in the Manhattan Project, and Seaborg joined the Met Lab to head up a major effort on the chemistry and technology of plutonium.

Three new highly secret projects were to be constructed, all in remote areas—Oak Ridge in Tennessee (Site X), Hanford in Washington State (Site W), and Los Alamos in New Mexico (Site Y). The first was Oak Ridge, which consisted of four major installations. The Oak Ridge facilities, operated by Tennessee Eastman, a subsidiary of Eastman

Kodak, had the task of developing and building a plant to recover the fissionable isotope, U-235, from natural uranium, which contains only 0.7% of this isotope, the remainder being non-fissionable U-238. Two approaches were investigated: electromagnetic separation by calutrons, which operate on the principle of a mass spectrometer, and gaseous diffusion, in which gaseous uranium hexafluoride (UF_6) is passed repeatedly through barriers having extremely fine pores. A third method of isotopic separation that was investigated was the use of gas centrifuges, but it was impossible at the time to build units that could operate at the extremely high speeds required to achieve any significant degree of separation.

In the gaseous diffusion process, the U-235 hexafluoride molecules, being just a bit lighter, pass very slightly more readily through the porous structure to provide a U-235/U-238 separation, but a very large number of stages are required to achieve the desired U-235 enrichment. (The composition and structure of the barrier material was one of the most closely guarded secrets in the nuclear program.) A plant for the electromagnetic separation process, Y-12, and one for the gaseous diffusion process, K-25, were constructed. A small thermal diffusion plant, S-50, was also built within K-25 to provide that facility with slightly enriched uranium. Although the plants could provide uranium of any desired enrichment, a level greater than 90% was required for weapons use. Later on, enrichments of approximately 3% were used for power reactors. A major consideration in the siting of the facility at Oak Ridge was a requirement for a prodigious amount of electric power, which could be provided only by a huge utility such as the Tennessee Valley Authority (TVA), to operate the uranium enrichment plant. The fourth installation at Oak Ridge was the Clinton Laboratory (X-10), which was concerned mainly with separation process research. A pilot plant to study plutonium recovery processes was built and operated. The X-10 facility was also used to train personnel for nuclear work at other sites.

Hanford, operated by I. E. du Pont de Nemours and Co., had the responsibility for plutonium production. This was accomplished by three large uranium-fueled reactors located near the Columbia River, which provided the necessary cooling water. During the reactor operation, a small concentration of plutonium is generated in the fuel by neutron capture. Periodically, some of the irradiated uranium (in the form of aluminum-clad slugs) is discharged and processed to separate the plutonium product. Fissioning of uranium also produces some three dozen fission-product elements, each of which has its own unique chemical properties and, most often, several isotopes with different radioactive emissions. Because of the many chemical elements involved, processing this discharged fuel was a formidable task. The uranium and plutonium products had to be recovered separately and free of any significant fission products. The high radiation levels required that the process, down to its final stages, consist of remotely controlled operations behind thick barriers of concrete shielding. The plutonium product was recovered initially by the Bismuth Phosphate process and subsequently by the Redox solvent-extraction process, both of which will be described later. The production of plutonium at Hanford began in 1944.

General Groves placed Robert Oppenheimer in charge of Los Alamos, where construction began in December 1942. The function of Los Alamos was to design, fabricate, and test the nuclear weapons, using the enriched uranium and plutonium from Oak Ridge and Hanford. This effort was more closely connected with the military and required the services of a number of well-known theoretical physicists supported by a large number of technical and service personnel. Oppenheimer later became a somewhat controversial figure during the

Communist "witch hunts" of the early 1950s and his security clearance was withdrawn, but there was never any evidence of disloyalty or wrongdoing on his part and he was later exonerated of all charges.

The Manhattan Project was conducted under the highest possible level of secrecy and with great urgency. It had a military atmosphere that was not always compatible with the personalities of some of the scientists. A major impetus was to end World War II without having to invade the Japanese homeland by amphibious assault, but there was also much concern over the possibility that the Germans might develop a deployable nuclear weapon before the war in Europe was over.

There was a sound basis for such concern, particularly in the early stages of the project. The German scientists had produced nuclear fission in the laboratory. They had also been looking at nuclear fusion and U-235 separations and were approaching criticality in a nuclear pile in a cave at Haigerloch. Their nuclear program was inhibited somewhat by a lack of enthusiasm on the part of Adolph Hitler, who believed the time frame was too long, and even more so by a serious miscalculation in its early stages. In 1941, one of their leading scientists, Walther Böthe, a highly regarded German physicist, greatly underestimated the diffusion path length of slow neutrons in graphite, apparently because graphite of inadequate purity was used in the German studies. Consequently, the German scientists selected heavy water as the moderator, rather than graphite, which was used in the U.S. program. The only significant source of heavy water available to them was at the Vermorsk power plant in southern Norway. Having gotten wind of what was going on, the British mounted a commando attack on that facility, followed by an RAF bombing raid which destroyed it. The British also sank a small ferry that was hauling heavy water to Germany. At the end of the war, an American intelligence force called *Alsos* quickly nabbed all the German nuclear documentation and scientists they could find to keep them out of the hands of the Soviets. (*Alsos* was a thinly disguised code name; in Greek it means "grove.") In addition, the U.S. Army Air Corps bombed the German nuclear production works near Berlin. Thus ended the German nuclear threat. Although General Groves was aware of this fact, he did not pass the information on to the scientists in the Manhattan Project.

The Manhattan Project was spectacularly successful in achieving its immediate objective. Three nuclear weapons were detonated in rapid succession: Almagordo, New Mexico (July 16, 1945), Hiroshima (August 6, 1945), and Nagasaki (August 8, 1945). The Almagordo and Nagasaki bombs were plutonium, and the one at Hiroshima was U-235. The reason for this was that the Los Alamos scientists were certain that the uranium bomb would work because its firing mechanism was straightforward. They were not so sure about the plutonium bomb, which required a more complex configuration and firing mechanism to assure sufficient detonation for an effective weapon, and they felt that a test shot was needed. At that time, the production of U-235 had been so slow that only enough was available for one bomb.

Although the tide had turned in favor of the allies in World War II by 1944, vicious fighting continued well into 1945—the Normandy landing, the Battle of the Bulge, Iwo Jima, Okinawa—and it appeared that many more American lives were yet to be lost. Victory in Europe came on May 7, 1945, but the Pacific war raged on until the nuclear weapons were used and Japan surrendered on August 15, 1945.

Even before Hiroshima and Nagasaki, there was a great deal of controversy, both in the scientific community and in government circles, as to the manner in which the nuclear weapons should be used. Some wondered whether a demonstration shot or the destruction of a military target such as the Japanese naval base on the island of Truk would achieve the objective of ending the war. Others advocated a direct attack on Japan itself to end the war quickly in order to save the lives of American servicemen. There were still others who were concerned about the moral aspects of using the weapons on Japanese civilians.

Harry S. Truman who was thrust into the presidency by the death of Franklin D. Roosevelt on April 12, 1945, had not been told of the existence of the nuclear weapons until that time. Secretary of War Henry Stimson briefed him on the situation. Joseph Stalin, at Potsdam, had committed the U.S.S.R. to enter the war against Japan within 90 days of VE Day. After extensive discussions with Stimson and other government officials, military people including Generals Dwight Eisenhower and George Marshall, and various scientific leaders in the Manhattan Project, Truman made his decision. That may have been the sort of thing he had in mind when he installed the motto "The buck stops here" in the Oval Office. Whether that was the right decision has been a matter of much conjecture and controversy for the last 50 years.

The year 1945 was fraught with many changes. When the war ended, the military forces were demobilized rapidly and the defense budgets were cut even more. Scientists in the Manhattan Project, feeling that their mission was accomplished, and, fed up with the oppressive security, left in large numbers. The question of civilian applications arose and continuing military control of atomic energy was debated. Policy questions about future uses and control of nuclear energy were being raised and the Federation of Atomic Scientists, based primarily at the Met Lab, was formed. Meanwhile, the report, *Atomic Energy for Military Purposes* by Henry D. Smyth, was released to the public. This report contained a surprisingly candid description of the Manhattan Project, but, as pointed out by Seaborg, it made only minor mention of the chemists and engineers at the Met Lab who had done an enormous amount of difficult, painstaking work on the development of plutonium chemistry and technology. (Seaborg rectified this situation in 1994 when he published his book, *The Plutonium Story: the Journals of Professor Glenn T. Seaborg 1939-1946.*) Also in 1945, a new dark cloud loomed on the horizon. Irving Langmuir, a well-known chemist, predicted that Russia would explode a nuclear weapon in five years. He was optimistic; it happened in 1949.

Early in 1946, the U.S. Navy, which had previously played only a minor role in the nuclear weapons program, conducted Operation Crossroads, which consisted of two fission bomb detonations on the Bikini Atoll in the Marshall Islands. The first test, "Able," was an atmospheric shot, and the second, "Baker," was underwater. Just prior to these tests, some of the sailors on U.S. Navy ships returning from World War II were startled to see a bright red battleship among the usual gray vessels in the fleet. Aware of the Hiroshima and Nagasaki shots the year before, they suspected something important was afoot but had no idea what it was. The red vessel turned out to be the U.S.S. *Nevada*, an aging battleship that had been selected to serve as the primary target for Operation Crossroads. The purpose of these tests was to determine how much damage warships would sustain near a nuclear weapon and to evaluate decontamination procedures. The *Nevada* actually survived the test and was finally disposed of by naval gunfire.

During this period, the question arose as to whether the U.S. nuclear programs should remain under control of the military, or if they should be brought under civilian jurisdiction. The military point of view that they should remain in control was introduced into Congress as the May-Johnson Bill, which was defeated. An alternative proposal favoring civilian control (the McMahon Bill) was accepted and passed by Congress in the form of the Atomic Energy Act of 1946.

THE ATOMIC ENERGY COMMISSION AND THE NATIONAL LABORATORIES

The main thrust of the Atomic Energy Act, which became effective January 1, 1947, was to transfer the U.S. nuclear effort from military to civilian control. It created the Atomic Energy Commission (AEC) under the executive branch of the government and the Joint Committee on Atomic Energy (JCAE) under the legislative branch. The original AEC consisted of five prominent public figures: David Lilienthal (Chairman), Lewis Strauss, Sumner Pike, Robert Bacher, and William Waymach. Bacher was the only technical person. The Joint Committee was made up of 18 senators and congressmen, with Senator Bourke Hickenlooper as the chairman. Although the military had relinquished overall management of the nuclear programs, they still maintained a strong influence as one of the four divisions of the AEC.

During the AEC "start-up" period of 1947-1950, a General Advisory Committee (GAC) provided technical advice and guidance for the new organization. Members of this committee were: Robert Oppenheimer (Chairman), Enrico Fermi, Walter Zinn, Isidor Rabi, Glenn Seaborg, Lee DuBridge, James Conant, Eugene Wigner, Frank Spedding, and Norris Bradbury.

This newly formed group of organizations faced a plethora of problems and decisions at the outset. Foremost was the Russian nuclear threat. It was clear that the U.S. would have to maintain a strong nuclear weapons program. The U.S.S.R., using captured German scientists and engineers, had developed a highly efficient technology for the separation and recovery of U-235, based upon ultra-high-speed gas centrifuges, and had produced large quantities of weapons-grade material. The U.S. continued to use the gaseous diffusion plants.

When the AEC was formed, scientists and engineers at the Met Lab and other sites began to propose many new potential uses for nuclear energy, the main one being civilian nuclear power generation. Breeder reactors were already under consideration. The idea of a nuclear-powered locomotive came up, but it was not pursued. Naval propulsion reactors were proposed, and Captain (later Admiral) Hyman Rickover, along with the General Electric Co., designed a nuclear power system for a destroyer escort. Shortly thereafter, work began on nuclear powered submarines and the U.S.S. *Nautilus* was launched in 1954. Work had started on the Nuclear Energy for the Propulsion of Aircraft project (NEPA) and this program lasted until 1961. The use of nuclear explosives for civil engineering projects (later called "Plowshare") was proposed. Biological and medical uses were considered to be highly promising. In addition to these and other applications of nuclear energy, scientists were agitating strongly for a greatly expanded effort on basic nuclear research, particularly in the area of particle physics.

When the AEC was formed, the principal facilities under its management were Argonne National Laboratory (formerly the Met Lab), the Oak Ridge complex, the Hanford facilities, and the Los Alamos Scientific Laboratory (then called LASL). Important work was also being done at various university laboratories, including Berkeley, Iowa State, and Columbia. The Clinton Laboratory was renamed Oak Ridge National Laboratory (ORNL) in 1948.

Several new installations were built during the next few years. Brookhaven National Laboratory (BNL), which grew largely out of the research group at Columbia, was founded on Long Island in 1947. Argonne, Brookhaven, and Oak Ridge, the three original

National Laboratories, are all multipurpose facilities at present. Edward Teller, who has been dubbed the "Father of the H-bomb" and was a staunch advocate of thermonuclear weapons, became dissatisfied with the Los Alamos program and proposed a new laboratory for that type of work. The result was the creation of what is now Lawrence Livermore National Laboratory (LLNL), located near Berkeley. Construction of the National Reactor Testing Station (NRTS) in the Idaho desert was begun in 1949. Fermi, Oppenheimer, and Seaborg felt that three major reactors (a breeder, a materials testing reactor, and a propulsion-type reactor) should be located at Argonne, but Teller pushed through the Idaho site. Several other special-purpose facilities were built in the late 1940s and the 1950s. A list of the principal U.S. nuclear facilities, some of which were built later, and others that are no longer operational, is given in Table 1-1.

In 1946, the Met Lab became Argonne National Laboratory with Walter Zinn as the Director. Zinn had been deeply involved in the Manhattan Project, including the operation of Fermi's original pile, and he served ANL in its early years as a highly competent, dynamic leader. This was undoubtedly the major factor in the AEC's decision in 1947 to center all the nation's nuclear reactor research at ANL. The Laboratory did, in fact, play a leadership, but not exclusive, role in the U.S. reactor research and development programs for several years. In 1947, General Groves approved the purchase of 3,700 acres of land in DuPage County, including the estate of a sausage magnate in the Chicago area by the name of Erwin Freund, as the future site for Argonne. With its new name and this "Site D" property, ANL began to develop into the institution we know now. The first Argonne picnic, which has become an annual event, took place on September 9, 1948.

THE MET LAB

In 1942, Arthur Compton had consolidated nearly all the national atomic research activities at the Met Lab, located at the University of Chicago. Most of the atomic physicists had been working at various East Coast universities, using different types of equipment and experimental approaches, and he felt that the effort should be more closely coordinated in one location. The group he assembled could well have been the largest collection of Nobel laureates and other renowned scientists ever to work together in one laboratory. In spite of the code name "Metallurgical Laboratory," as Laura Fermi once pointed out, there wasn't a single metallurgist in the entire group at the time. The task of this group was to provide the scientific and technical "know how" that was desperately needed in planning and constructing the facilities at Oak Ridge, Hanford, and Los Alamos. As those facilities became a reality, many people were transferred to them from the Met Lab to provide the technical leadership and expertise that was needed to get them into operation.

Life at the Met Lab for the workers and their families was quite different from that at the newer sites where they lived in "secret" company towns in remote locations, basically cut off from civilization. The entire towns, enclosed by fences, were under complete control of the Army, which provided the necessities, but few luxuries, for schools, housing, shopping, and other ordinary needs of a family, and security was at the highest possible level. At Los Alamos, there were no individual mailing addresses, and incoming and outgoing mail was censored. In contrast, most of the Met Lab workers and their families lived in the Hyde Park area of Chicago in rental apartments or houses, and their children attended the Chicago schools. The workers walked or commuted to work by public

Table 1-1. Major U.S. Nuclear Facilities

Multipurpose Laboratories[a]

- Argonne National Laboratory (Univ. of Chicago)
- Brookhaven National Laboratory (Associated Universities, Inc.)
- Oak Ridge National Laboratory (Martin-Marietta)

Uranium Enrichment Plants

- Oak Ridge, TN (Union Carbide): UF_6 diffusion plant
- Portsmouth, OH (Goodyear Aerospace): UF_6 diffusion plant
- Paducah, KY (Union Carbide): UF_6 diffusion plant

Materials Processing Plants

- Ashtabula Feed Materials Plant, OH (Reactive Metals): Fabricate metal parts from depleted and low-enriched uranium for production reactors and bomb parts
- Fernald, OH (National Lead): Same as Ashtabula
- Idaho Chemical Processing Plant (ICPP), Idaho Falls (Allied Chemical): Unburned enriched uranium (mostly from submarines) removed from used fuel rods and sent on for recycling
- Hanford Production Operations, Richland, WA (Rockwell Hanford and United Nuclear): Generate plutonium in reactors, separate and recover it by reprocessing, then send it on for bomb parts
- Savannah River Plant, Aiken, SC (E. I. DuPont): Same as Hanford. Also prepares deuterium as heavy water and makes tritium by irradiation of lithium in the reactors

Weapons Fabrication Plants

- Kansas City Plant, MO (Bendix): Electronic and mechanical weapons parts
- Mound Laboratory, Miamisburg, OH (Monsanto Research): Special small high-explosive components and radioisotope batteries for bombs; uses Pu-238 from Savannah River
- Savannah River Weapons Facility, Aiken, SC (E. I. DuPont): Fabrication of uranium and lithium deuteride parts
- Y-12 Plant, Oak Ridge, TN (Union Carbide): Same as Savannah River Weapons Facility
- Pinellas Plant, St. Petersburg, FL (General Electric): Makes neutron trigger bombs
- Rocky Flats Plant, Golden, CO (Rockwell International): Fabrication of plutonium metal parts
- Pantex Plant, Amarillo, TX (Mason and Hangar-Silas Mason): Fabrication of larger high-explosive parts, assembly of weapons from components, recycle of old warheads

Weapons Research & Development

- Los Alamos National Laboratory, Los Alamos, NM (U. of CA)
- Lawrence Livermore National Laboratory, Livermore, CA (U. of CA)
- Sandia Laboratories, Albuquerque, NM (Western Electric)
- Nevada Test Site, Las Vegas, NV (Reynolds Electrical & Engineering)

Naval Nuclear Propulsion

- Bettis Atomic Power Laboratory, West Miffin, PA (Westinghouse)
- Knolls Atomic Power, Schenectady, NY (General Electric)

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[a] At the present time, the multiprogram laboratories also include Idaho National Engineering and Environmental Laboratory (INEEL), Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Pacific Northwest National Laboratory (PNNL), and Sandia National Laboratories (SNL).

transportation and generally lived a rather normal life, except for the long hours and the extreme security. They were, of course, like all other civilians, subject to war-time rationing of gasoline, meat, sugar, butter, shoes, tires, and other items and to the nationwide 35-mph speed limit.

As early as 1943, some of the Met Lab workers began to be concerned about its future prospects. The Met Lab was being used as a training facility for personnel at the new nuclear labs and plants and many of the staff personnel were being siphoned away. It was clear that the weapons work would continue to be taken over by others. Nevertheless, there was still plenty of work that needed to be done, and programs continued at the Met Lab in several areas of nuclear research, including many of the early studies on radiation safety and health physics. The two programs that were most pertinent to the future interests of the Chemical Engineering Division at Argonne were reactor physics and development work on processes for the recovery of plutonium from irradiated uranium reactor fuels.

Most of the reactor research at the Met Lab and, later, Argonne, in the 1940s and early 1950s, involved the "CP" (Chicago Pile) series of reactors listed in Table 1-2.

In 1943, the CP-1 pile was disassembled and removed to a site in the Argonne Woods (now the Red Gate Woods) in Palos Hills about two miles southwest of Willowbrook, where it was enlarged somewhat, renamed "CP-2," and used for further reactor physics experiments. This location was designated "Site A," and is the source of the name Argonne. It is accessible from Archer Avenue through the Red Gate entrance, but the only evidence today of its previous existence is a grassy mound with a small marker.

CP-3 had a higher power level, and employed heavy water instead of graphite as the moderator. It was used primarily for reactor physics research that involved neutron optics studies, cross-section measurements, the effects of oscillation, and other phenomena of interest. After CP-3 had operated for six years, the natural uranium fuel was replaced with an alloy of 2% highly enriched uranium in aluminum; this version was called CP-3'.

People sometimes ask, "Why isn't a CP-4 on the list?" There was, in fact, a reactor design that started out as CP-4 in its early stages, but it eventually became transformed into Experimental Breeder Reactor I (EBR-I), which is another story.

Table 1-2. CP Series of Reactors

Reactor	Location	Power	Fuel	Moderator	Operation
CP-1	West Stands	200 W (max.)	Natural U Metal, Oxide	Graphite	12/2/42
CP-2	Site "A" Palos Park	200 W-2 kW	Natural U Metal, Oxide	Graphite	1943-1954
CP-3	Site "A"	300 kW	Natural U Metal	Heavy Water	1944-1950
CP-3'	Site "A"	300 kW	98% Al-2% Enriched U	Heavy Water	1950-1954
CP-5	Site "D" (DuPage Co.)	1,000 kW	98% Al-2% Enriched U	Heavy Water	1954-1979

The last of the series, CP-5, was similar to CP-3', but it was larger and designed to accommodate a wide variety of users. It was used extensively by ANL scientists from the various divisions, as well as many others from universities and industrial laboratories. Two novel features were of much interest and utility. One was a neutron chopper operating on the same general principle as a time-of-flight spectrometer, which could provide a neutron beam at a specific energy level, thereby permitting cross sections or other nuclear data to be determined as a function of neutron energy. The other feature was a "rabbit" that could be passed through the reactor *via* a pneumatic tube, so a sample could be recovered very quickly for short half-life measurements. Both features were used occasionally by members of the Chemical Engineering Division.

Early in the Manhattan Project, a decision was made to pursue both uranium-235 and plutonium-239 as fissionable materials for nuclear weapons. As mentioned earlier, the uranium-235 could be recovered from natural uranium either by electromagnetic separation or by gaseous diffusion of the hexafluoride; both approaches were pursued immediately at the Oak Ridge installation. The recovery of plutonium was a more challenging problem because it first had to be generated through neutron capture by uranium in a reactor, and then separated chemically from the uranium and fission products. It was this program that eventually spawned the Argonne Chemical Engineering Division.

The first work on this type of separation was performed at the University of Chicago by a small group of chemists, some of whom had been involved in the early studies of plutonium by Seaborg's group at Berkeley in 1940. The initial studies were done in the Kent Laboratory and the George Herbert Jones Laboratory. As the effort expanded, most of the research on plutonium was transferred to a temporary building, called "New Chem," which was erected in 1943 on the northwest corner of the University of Chicago campus. Subsequent work on the engineering aspects of the separations processes was located beneath the West Stands of Stagg Field, with semiworks facilities in the area of the squash court where the original CP-1 pile had been. A second floor housed chemical research and analytical laboratories. (The term "semiworks" refers to small-scale engineering development work on equipment, operating conditions, and general feasibility of process operations as opposed to a pilot plant, which is usually a small prototype of a specific full-size plant.) At that time, and throughout the existence of the Chemical Engineering Division, an analytical laboratory has been essential because of the large number of chemical and radiochemical analyses needed to determine the effectiveness of the separation procedures that were under development.

The first order of business was to develop a process as quickly as possible for the recovery of plutonium that was to be bred in the irradiated uranium fuel of the Hanford reactors. When Seaborg arrived at the Met Lab in 1942, some information was available on the chemistry of plutonium from the work he and his coworkers had done at Berkeley. However, a huge amount of creative, meticulous research was necessary to obtain the information needed to develop a full-scale plutonium recovery process. In addition, the nuclear physicists concerned with weapons design were desperate for data on the physical properties of metallic plutonium, such as density, hardness, and phase transitions. At the outset, only sub-microgram quantities of plutonium, which had been generated by irradiating several hundred pounds of uranium oxide in a 45-in. cyclotron at Washington University in St. Louis, were available. The irradiated uranium was moved from St. Louis to Chicago by personal car or truck in wooden and Masonite® boxes shielded internally with lead bricks and often of questionable integrity.

The only analytical method for plutonium at that time was radiation counting.

The first plutonium to be observed visually was about one microgram of the fluoride that was isolated in pure form on August 20, 1942. Later on, milligram amounts began to be produced, making the work considerably easier. The amount of information on the chemistry and physical properties of plutonium and its compounds that Seaborg and his associates were able to generate in a short time is astounding, especially when one considers the micro scale of the work.

An interesting sidelight of this program was an effort to develop a convenient nomenclature for the various isotopes and materials. A convention that one still runs into occasionally in conversation or the older literature is an isotope naming system in which the actinide isotopes are identified by the last digit of the atomic number and the last digit of the atomic weight; *e.g.*, 28 is U-238, 25 is U-235, 49 is Pu-239, and 39 is Np-239.

The primary task of Seaborg's group at the Met Lab was to develop a procedure for separating weapons-grade plutonium from uranium and fission products. Several avenues were explored, one of which was the Bismuth Phosphate ($BiPO_4$) process. This was a batch precipitation procedure that separated plutonium from the uranium and fission products by a series of $BiPO_4$ precipitations from aqueous solutions. Plutonium was coprecipitated with the $BiPO_4$ in the tetravalent state and left in solution in the hexavalent form. Final purification of the plutonium was achieved by a similar precipitation cycle, using lanthanum fluoride (LaF_3) as the carrier precipitate. Uranium, along with the fission products, was discarded to waste. (A solvent-extraction process was used several years later to recover the uranium.) The process met the immediate objective by recovering plutonium with greater than 95% efficiency and a ten-million-fold removal of fission products, *i.e.*, a decontamination factor of 10^7, and it was put into full-scale operation at Hanford in 1944. The elapsed time between the first visual observation of plutonium (as a fluoride) and full-scale production at Hanford was only two years. This billionfold scale-up from microgram to kilogram quantities in one step was an incredible achievement.

The Bismuth Phosphate process did, however, have serious disadvantages—the multiple batch operations, the inability to recover uranium, the large quantities of process chemicals that were required, and the large volume of process wastes. For these reasons, a search was begun for processes having a potential for higher capacities, improved efficiency, and lower costs, as well as a capability for a three-way separation of uranium, plutonium, and fission products.

Some experience was already available on the use of solvent-extraction processes to extract uranium from leach liquors produced during processing of the ore. In the processing of discharged reactor fuels, the fuel material was first dissolved in an aqueous solvent, which was normally nitric acid (HNO_3). Separation of the actinide elements from each other and from the fission products was then accomplished by repeated extractions between the aqueous solutions and an organic solvent in continuous, multistage equipment such as packed columns. Partitioning of the various elements between the two phases depends on the compositions of the aqueous and organic phases and can be manipulated through the use of oxidants, reductants, salting-out agents, and complex-forming compounds.

Solvent-extraction processes offered the potential advantages of continuous operation in multistage, countercurrent extraction devices in which separation factors are multiplied manyfold to achieve very high fission-product decontamination factors (typically 10^6-10^9), and excellent recovery (>99.5%) of uranium and plutonium. Processes of this type also have the advantage that they avoid the materials handling problems associated with solids.

Preliminary studies of solvent-extraction processes were conducted at the Met Lab. The results were sufficiently promising that an increased effort was justified and extraction columns were set up in the West Stands for this purpose.

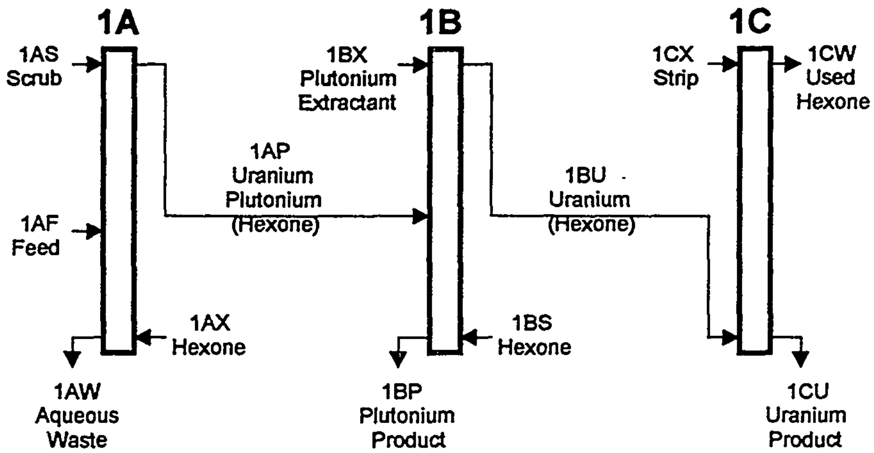
Seaborg, realizing that solvent-extraction technology was a specialized field, knew that he had to find an expert to continue the work, and in 1944 he asked Dr. Stephen Lawroski to direct the effort. Lawroski, a recognized authority in solvent extraction, had studied under Professor Merrill Fenske and received a Ph.D. at Pennsylvania State University. He was employed by the Standard Oil Development Company at the time. At the request of the Manhattan District authorities, he was placed on loan to the Met Lab for two years. Later on, he became the original director of the Argonne Chemical Engineering Division.

The initial assignment of Lawroski's group at West Stands was to develop process compositions and equipment to achieve ultra-purification of Hanford plutonium from light element impurities. This requirement stemmed from concern by nuclear weapon designers at Los Alamos that alpha particles from the decay of plutonium would interact with the light elements to produce neutrons prematurely and thereby cause a major reduction of explosive power of nuclear weapons using plutonium. The West Stands group soon demonstrated that solvent extraction could, indeed, achieve ultra-purification of plutonium. That achievement of itself, however, turned out to be useless when it was learned that the Hanford plutonium contained a small, but significant amount of a spontaneously fissioning isotope of plutonium that would still result in the premature presence of neutrons. This meant that the weapons scientists had to develop a plutonium weapon design entirely different from that used for the U-235 weapon. To increase the velocity with which the subcritical masses of plutonium were forced together, explosive charges surrounding the plutonium were shaped into a "focusing lens" configuration that would create a very rapid implosion.

Despite the situation just described, the work of the West Stands group was not terminated. It was instead redirected to take advantage of the potential already demonstrated for solvent extraction by that group and new information on the chemistry of plutonium that had been generated by Seaborg's chemists at New Chem. The redirected effort ultimately culminated in the Redox process, which, after pilot-plant tests at Oak Ridge, was applied in 1951 on a production scale at Hanford to recover decontaminated plutonium and uranium separately. Replacement of the cumbersome Bismuth Phosphate process by the Redox solvent-extraction process at Hanford resulted in an enormous cost saving that paid for the new $50 million plant within only two years.

A simplified schematic flowsheet for the first cycle of a Redox process is shown in Fig. 1-1 to illustrate how the basic separations of uranium, plutonium, and fission products were made. Hexone (methyl isobutyl ketone) was used as the organic solvent, and aluminum nitrate, $Al(NO_3)_3$, served as a salting agent in the aqueous nitric acid phase to increase the distribution of uranium and plutonium into the hexone. In this, as well as in later processes, plutonium was separated from uranium by reducing the plutonium to the trivalent state, in which it strongly favors the aqueous phase. Figure 1-1 shows only the first cycle; in practice, one or two additional uranium and plutonium purification cycles consisting only of extraction and stripping operations are added, since complete partition of the uranium and plutonium occurs in the first cycle. The additional cycles result in much higher fission-product decontamination factors and in product recoveries greater than 99.5%.

Solvent-extraction processes for reactor fuels tend to be generic in nature in that they all involve dissolution of the fuel in acid,



The spent reactor fuel is dissolved in nitric acid and a strong oxidant such as sodium dichromate ($Na_2Cr_2O_7$) is added to convert all the uranium and plutonium to the hexavalent state (stream 1AF). When in the hexavalent state, the uranium and plutonium tend to favor the organic (hexone) (1A) phase, and a scrub stream (1AS) containing aluminum nitrate [$(Al(NO_3)_3)$] as a salting agent enhances this effect. The fission products remain in the aqueous phase (1AW), which is discarded as waste. In the 1B column, stream 1BX is an aqueous solution of nitric acid and a reducing agent such as ferrous sulfamate [$(Fe(H_2NHSO_3)_2)$], which reduces the plutonium selectively to the trivalent state. Trivalent plutonium favors the aqueous phase and is recovered in the product stream, 1BP. In column 1C, a dilute solution of nitric acid, stream 1CX, is used to extract the uranium from the hexone back into the aqueous phase, which becomes the uranium product stream, 1CU. The used hexone, stream 1CW, is recovered and recycled.

Fig. 1-1. Flowsheet for First Redox Cycle

followed by a series of extractions between the acidic aqueous solution and an organic solvent. The types and efficiencies of the separations that can be made, however, are affected markedly by the compositions of the two solvent phases, and most of the progress that was made in this technology resulted from investigations of a wide variety of organic solvents and complexing and salting agents. The design of the equipment is also important because it determines the throughput rate of the process, the efficiency of the separations and the methods for handling the input and product streams. Basic studies were conducted in which the effectiveness of extractants was correlated with acid-base theory, and the settling rates and interfacial areas of the immiscible liquids were related to the physical properties of the liquids. In the early small-scale engineering studies, the extraction columns consisted of 1-in.-diameter glass pipe packed with glass helix rings about 1/4 in. in diameter. These countercurrent columns, which were up to 20 feet in height, were operated by remote control behind heavy concrete shielding, and were pulsed in some cases. Later on, in the Argonne Chemical Engineering Division, most of the solvent-extraction work was done initially with 1-in.-diameter stainless steel columns packed with 1/4-in. Raschig rings (hollow cylinders). These columns, up to 30 feet in height, were located behind concrete shielding in the high-bay area of Building D-205 and were operated remotely. As the development studies on solvent extraction progressed, other contacting devices such as mixer-settlers and stacked-stage extractors came into the picture because of their high efficiency and flexibility of layout in a full-scale plant.

Following the development of the Redox process, the Canadians developed the Trigly process, which employed triglycol dichloride as the organic phase in the head-end cycle and hexone in the subsequent cycles as in the Redox process. The Butex process, which used dibutyl carbitol as the organic solvent, was developed at Oak Ridge. An advantage of this process is that no additional salting agent is required in the nitric acid solution, so the nitric acid can be recovered by evaporation and the fission-product waste volumes can be reduced. The Butex process is still used at the Y-12 plant in Oak Ridge for the recovery of enriched uranium.

A major advance was made in nuclear fuel reprocessing when workers at Oak Ridge originated the Purex process. The solvent in this process is tri-*n*-butyl phosphate (TBP) diluted with a kerosene-type hydrocarbon such as dodecane. This solvent has a strong affinity for uranium and plutonium and is able to extract their nitrate salts from nitric acid solutions. The Purex process has several advantages over the Redox process—elimination of nonvolatile salting agents, lower solvent volatility and flammability, high chemical and radiation stability of the solvent, and lower operating costs. The Purex process was tested on a pilot-plant scale at Oak Ridge National Laboratory and installed in the plutonium production plants at Hanford and Savannah River. At Hanford, it replaced the Redox process.

The diversity of solvent-extraction schemes that were investigated at the Met Lab, Argonne, and elsewhere after the Redox work was completed is too great for a detailed description of each, but Table 1-3 lists most of the processes, or variations thereof, which have been investigated at one time or another.

Solvent-extraction processes are still under investigation. The current work is concerned mainly with the TRUEX Process, which has the capability to separate the long-lived transuranium elements, such as neptunium, curium, and americium, from fission-product waste streams.

Work on the Redox solvent-extraction processes was continuing at the time the Chemical Engineering Division was formed. According to a report (ANL-4110) issued in January 1948, a month before the new division came into being, the organization of the Process Chemistry Group in the Chemistry Division was as follows:

<u>Group Leader</u>: Herbert Hyman

<u>Assistant Group Leader</u>: John Schraidt

<u>Semi-Works Operations</u>: John Schraidt, Phil Fineman, George Bernstein, Les Coleman, Lee Gaumer, Sherman Greenberg, Dave Jacobson, Jim King, Milt Klein, Harry Litland, John Natale, Laury Ross, Art Shor, and Bill Walters

<u>Laboratory Operations</u>: Harold Evans, Sy Vogler, and Eugene Hausman

<u>Analytical Operations</u>: Al Jonke (head), Olga Fineman, Jodie Hoekstra, and Carolyn Kennedy

This group was under the direction of Dr. Lawroski, who, at that time, was the Associate Director of the Chemistry Division in charge of process development.

Table 1-3. Solvent-Extraction Processes

Process	Solvent	Salting Agent(s)	Irradiation Fuel	Recovered Products
Redox	Hexone[a]	HNO_3, $Al(NO_3)_3$	Natural U	U, Pu
Purex	TBP[b] in Hydrocarbon[c]	HNO_3	Natural U	U, Pu
Butex	Dibutyl Ether or Ethylene Glycol	HNO_3, NH_4NO_3	Natural U	U, Pu
Halex	TBP in CCl_4	HNO_3	Natural U	U, Pu
Hexone 25	Hexone	HNO_3, $Al(NO_3)_3$	Enriched U-Al	Enriched U
Zr Alloy	TBP in Hydrocarbon	HNO_3, $Al(NO_3)_3$	Enriched U-Zr	Enriched U
Thorex	TBP in Hydrocarbon	HNO_3, $Al(NO_3)_3$	Thorium	Th, U-233
Ether	Diisopropyl Ether	$Th(NO_3)_4$, $Al(NO_3)_3$	Th-Al	U-233

[a] Methyl isobutyl ketone.
[b] Tri-*n*-butyl phosphate.
[c] Kerosene-type solvents such as dodecane.

THE CHEMICAL ENGINEERING DIVISION

The story of the Chemical Engineering Division begins with Dr. Stephen Lawroski, who was its original Division Director. Dr. Lawroski received a doctorate in chemical engineering in 1943 from Pennsylvania State University. While doing his graduate work, he was employed as a Research Assistant at the Petroleum Refining Laboratory at State College, Pennsylvania, where he was one of the principal staff members working on high-efficiency packing materials for distillation and solvent-extraction equipment. As mentioned earlier, he spent two years at the Met Lab from 1944 to 1946 on loan from the Standard Oil Development Company (later named the EXXON Research and Engineering Company). There, he directed a group engaged in the development of solvent-extraction processes for the recovery and purification of uranium and plutonium from Hanford plutonium production reactors. This group, under his leadership, was highly productive

Fig. 1-2. Stephen Lawroski

and its work led to the Redox process. In 1946, he returned to the Standard Oil Development Company as Assistant Section Chief of the Manufacturing and Process Section of the Research Division. In September of that year, however, his company recommended him for atomic energy training as an Advanced Professional Trainee at the Clinton Laboratory, where he remained until June 1947. This assignment offered the opportunity to study reactor and separations technology, including the solvent-extraction pilot plant that had been built to test the large-scale Redox process for the Hanford facility.

From Argonne's standpoint, one of the most valuable results of this assignment was that Dr. Lawroski, in part due to his gregarious personality, made many friends among the other engineers, scientists, and trainees. Later on, he persuaded some of these people (Hal Feder, Milt Levenson, Walt Rodger, Les Coleman, and Les Burris) to come to work at ANL. He also became acquainted with a number of other people who later became important contacts in the AEC and the other national nuclear establishments.

From Dr. Lawroski's viewpoint, he would no doubt be the first to agree that by far the most valuable asset he acquired at the Clinton Laboratories was his new bride, Helen, who had been working in their Health Physics Division.

When Dr. Lawroski returned to the Chicago area in July 1947, he accepted employment as head of the Process Development Section and Associate Director of the Chemistry Division (CHM) and the section under Herbert Hyman became one of his responsibilities. Early in 1948, Dr. Zinn approached Dr. Lawroski with the proposal that ANL should establish a Chemical Engineering Division (CEN) with him as director. Thus, the Chemical Engineering Division was born in February 1948. Soon thereafter, Zinn presented him with an interesting choice. As the Laboratory was moving to the present DuPage site, the Chemical Engineering Division was given the option of moving to the new DuPage site within about a year if it were willing to move into military-type Quonset buildings. Or, if it preferred to wait another year, it could have new buildings built specifically to meet its requirements. That was the genesis of Buildings D-205 and D-310. Members of the Division who remember the leaky, drafty Quonset buildings occupied by the Administration, Travel Office, Graphic Arts, Health Services, and other ANL organizations for several decades can appreciate the benefits of the choice that was made. Some of the longer-term employees will remember the annual physical examinations, in which the procedure, after the chest x-ray and blood sample, was for the patient, essentially unclothed, to wait in a small room for 30 to 45 minutes for the doctor to show up. During the winter in that leaky Quonset hut, "cooling your heels" was an understatement.

Fig. 1-3. Herbert Hyman

Building D-310, which was completed first, was designed originally as a structure for experimental processing, storage, and shipping of radioactive wastes. A high-level gamma irradiation facility was added later. This consisted of a so-called "swimming pool" into which irradiated reactor fuel assemblies could be lowered by a crane. The pool was filled with water to provide thermal cooling and radiation shielding. The building was occupied initially by an incinerator and scrubber for processing dry active wastes and various pieces of equipment for treating active liquid wastes. Later on, Building D-310 served as a general-purpose area for a variety of projects that involved large equipment.

Building D-205 was much larger than D-310, and was planned to meet all the other needs of the Division, including engineering and chemistry laboratories, office space, drafting rooms, a library, conference rooms, shops, and a number of other facilities. These buildings will be described in more detail in the next chapter. The exodus of CEN personnel from the West Stands to the DuPage site began in 1950 and was completed in 1951.

Les Burris, who shared an office with Charlie Stevenson, tells of the time when Charlie, deeply involved in the planning of the new buildings, had a habit of laying large blueprints on a table where Les had been working with secret documents. The result was a series of security violations that got Les into some hot water.

Another incident that occurred during this period was the case of a new staff member who had not yet become fully familiarized with the operating procedures. People walking by his office one day noticed smoke emanating from the door. At that time, each office was provided with a red wastepaper basket labeled "BURN" for disposal of classified papers and he had taken it literally. Rumor has it that this happened more than once. Burn baskets, if used today, would most likely come with an operating manual and training sessions.

When the Division was formed, Dr. Lawroski made a policy decision that probably had a more profound effect than any other single factor on the nature of its future work. He believed that process development should be an integrated effort from the test tube to plant design. Thus the major programs often included basic and applied lab-scale research, basic engineering studies, equipment development, engineering design, materials development, pilot plant or semiworks testing, conceptual plant design, and some economic evaluations. With this type of organization, team efforts could include whatever particular talents were needed at any stage of process development, and much of the work could be done in parallel instead of sequentially. It also expedited feedback of problems for further work. The basic chemistry and engineering studies, although directed toward solutions of practical problems, were most often performed with the care and scope necessary to produce quality publications in the basic scientific and engineering journals. At the same time, these resources were available for troubleshooting on problems arising in the process development work.

The combination of engineers and scientists in the Division made for some interesting interactions. A certain amount of good-natured ribbing occurred in which the engineers referred to the chemists as "pharmacists" or something similar, and the chemists referred to the engineers as "pipefitters," but there was a mutual respect between the two groups. In fact, it was not unusual to find an engineer working with test tubes or a chemist assembling pipes and valves. The engineers most often used the English system of measurement, which made sense because the process equipment was almost always sized in those units. The chemists, however, had been brought up with the metric system and their equipment used those units. Both groups had to become bilingual in this respect, and both ANL and the Federal Government to this day are continuing to cope with this problem in the written materials that are issued. This general problem gave the basic scientists a special appreciation for the engineers' penchant for dimensionless numbers.

As a first step in implementing this policy, Dr. Lawroski, in order to complement his own training and experience as a chemical engineer, hired a highly qualified chemist to serve as the Associate Division Director. The man he selected was Dr. Charles Stevenson, who had earned a Ph.D. in organic chemistry at Pennsylvania State University and then worked as a research chemist at the Standard Oil Development Corporation and the Diamond Glass Company. Lawroski and Stevenson had been colleagues and personal friends both at Penn State and at Standard Oil. Charlie was a highly competent, affable individual, and he brought a new dimension to the Division.

Fig. 1-4. Charles Stevenson

The core personnel of the new Chemical Engineering Division were basically those from the Process Development Section of the ANL Chemistry Division plus new hires, including those from the Clinton Laboratory at Oak Ridge. People who were at the Met Lab in the early days and in the Chemical Engineering Division after it was formed include Elton Turk (1942), Milt Ader (1944), George Bernstein (1944), Phil Fineman (1944), John Schraidt (1944), Les Coleman (1946), Harold Evans (1946), and John Natale (1946). Milt, George, John, and Phil were members of SED (Special Engineering Detachment) of the U.S. Army during part of the time. Don Webster, who joined the Division much later and served as an Associate Division Director, had also spent a short time at the Met Lab in 1942-43. Marvin Tetenbaum spent some time at the Met Lab in 1942, returned to New York to obtain a Ph.D., worked at Columbia University for a time, and came to CEN several years later. The people from Oak Ridge (Hal Feder, Walt Rodger, Milt Levenson, and Les Burris) brought with them a great deal of practical experience in radiochemistry and hot pilot-plant operations. In 1949, Richard Vogel, who had received a Ph.D. in physical chemistry at Harvard University and was on the faculty of the Illinois Institute of Technology, was hired as a Senior Chemist, and was destined to succeed Dr. Lawroski as the Division Director several years later. Victor Munnecke, a chemical engineer, became the Assistant Division Director, and was responsible for the administrative and financial affairs of the Division. Ed Peterson had the primary management responsibility for the new buildings.

Once the Division was established, it expanded rapidly, both in manpower and in the scope of the work. Nearly all of the work during 1948 and 1949 continued to be directed toward solvent-extraction processes. A large program under Walt Rodger was concerned with the use of acid-deficient solvent-extraction flowsheets that had been proposed by Oak Ridge and later by Hanford. Some of the studies were done with extraction columns and others with two 20-stage mixer-settler units in which all the stages could be sampled simultaneously to obtain equilibrium data. These were especially useful in constructing equilibrium diagrams for various operating conditions. Individual studies were conducted on the precipitation of plutonium oxalate in columns, the behavior of neptunium, and the possibility of volatilizing ruthenium from solutions by oxidation to RuO_4 with oxygen-ozone mixtures.

Because the breeder reactor concept had become popular both at ANL and in the AEC, interest began to develop in the reprocessing of breeder reactor fuel. Recovery of Experimental Breeder Reactor and Materials Test Reactor fuels had been demonstrated in the Oak Ridge pilot plant. One such ANL program, headed by Les Burris, was the development of a simpler tributyl phosphate (TBP)-methylcyclohexane process for the recovery of highly enriched uranium from experimental EBR cores. This process proved to be capable of achieving the requisite fission product removal (a decontamination factor of 10^5) and uranium recovery (>99.9%) in a single solvent-extraction cycle. Sixteen runs with active feed material from Hanford that were conducted in the shielded columns in the high bay section of Building D-205 showed that the process could meet the requirements. While this work was still in progress, however, the AEC issued an edict that the bulk of the EBR fuel would be processed at the Idaho site, and the TBP process would be used at ANL only for analytical samples and cleanup operations.

That research is covered in a 1950 report, which credits the work to this group of people:

Project Leader: Les Burris, Jr.

Laboratory Group: Richard Vogel, Harold Evans, Morris Beederman, Bob Hildebrandt, Homer Tyler, and Bob Schablaske

Semi-Works Group: Walt Rodger, John Schraidt, John Natale, Lee Gaumer, Ed Hykan, John Loeding, Alex Aikens, Virgil Trice, Ira Dillon, Don Hampson, Norm Levitz, Les Coleman, Les Dorsey, Elmo West, Herb Brown, and Bill Voss

Pulse Column Group: Kegham Varteressian, Milt Levenson, and George Bernstein

Analytical Group: Doug Krause, Betty Reilly, Corky Thompson, Vincent Story, Chuck Seils, Jackie Williams, Larry Marek, Cynthia Hall, John Breeden, and Myron Homa

Some work was performed on the recovery of simulated Mark I naval reactor fuel, which was an enriched uranium-zirconium alloy. A Redox-type process seemed to be the best choice for this type of fuel, but it could not be dissolved in nitric acid because of its high zirconium content. Hydrofluoric acid with aluminum nitrate proved later to be the most promising solvent for this alloy.

One of the early processes initiated in the late 1940s and developed by the Division was of considerable import for recovery of tritium from irradiated lithium-aluminum alloy. Tritium was needed for the development of thermonuclear weapons (H-bombs). Tritium (hydrogen-3) is generated by irradiation of lithium-6 with neutrons, which results in the alpha reaction:

$$_3Li^6 + {}_0n^1 \rightarrow {}_1H^3 + {}_2He^4$$

Bernie Abraham of the Chemistry Division had proposed the use of lithium-aluminum alloy for this purpose. The tritium and helium recovery process consisted of heating the irradiated alloy to just below its melting point (about 600°C) at which temperature the gases, principally hydrogen-3 (tritium), helium-3, and helium-4, are released. The gases were pumped off, passed over uranium turnings at 800°C to remove any gaseous contaminants such as oxygen or moisture, and then through a palladium barrier to separate the helium isotopes from the tritium. The palladium barrier, a disc in the line maintained at a temperature of several hundred degrees Celsius, was permeable by the tritium, but not by the helium. This process was installed at

Hanford and later in the Savannah River production plant where it has been used for many years.

Development work was also initiated on the fluoride volatility process, in which uranium in the fuel was fluorinated to form uranium hexafluoride (UF_6). The UF_6 is volatile and can be separated from the other fuel constituents by vaporization or distillation. The rationale behind this process was that the decontaminated uranium product is in the form of a fluoride, which is directly suitable for reconversion to the metal, and the fission-product wastes would be a small volume of solid fluorides.

The idea of recovering uranium and plutonium by volatilization of the hexafluorides was not new. As early as 1942, Harold Urey had suggested the possibility of volatilizing uranium as the hexafluoride to separate it from plutonium. That same year Harrison Brown and Orville Hill at the Met Lab fluorinated the tetrafluorides of uranium and plutonium completely to the hexafluorides and suggested the procedure as a method for separating them from fission products. Fluorination studies continued off and on in the Met Lab for several years. Fluorine research was also in progress, particularly on the plutonium fluorides at Los Alamos. In 1944, Seaborg, in a systematic review of the stabilities of the actinide metal halides, concluded by analogy that plutonium hexafluoride (PuF_6) should be marginally stable, which was borne out by later experimental studies. The use of elemental fluorine as a fluorinating agent for metallic fuels did not work out well because of heat-transfer problems and irregular reaction rates. Joe Katz and Herbert Hyman of the Chemistry Division did some preliminary work on the use of halogen fluorides, such as ClF_3, BrF_3 or BrF_5, which are liquids. Bill Mecham and Milt Levenson conducted an experiment in the Chemical Engineering Division in which 10 g of irradiated uranium metal was dissolved in a BrF_3-BrF_5 mixture. The uranium dissolved smoothly and the UF_6 product was distilled off. The gross gamma decontamination factor was 2,000, and over 97% of the plutonium was in the residue. The only detectable fission-product activity in the UF_6 was tellurium. These results were highly encouraging and the fluoride volatility process became a major program in the 1950s.

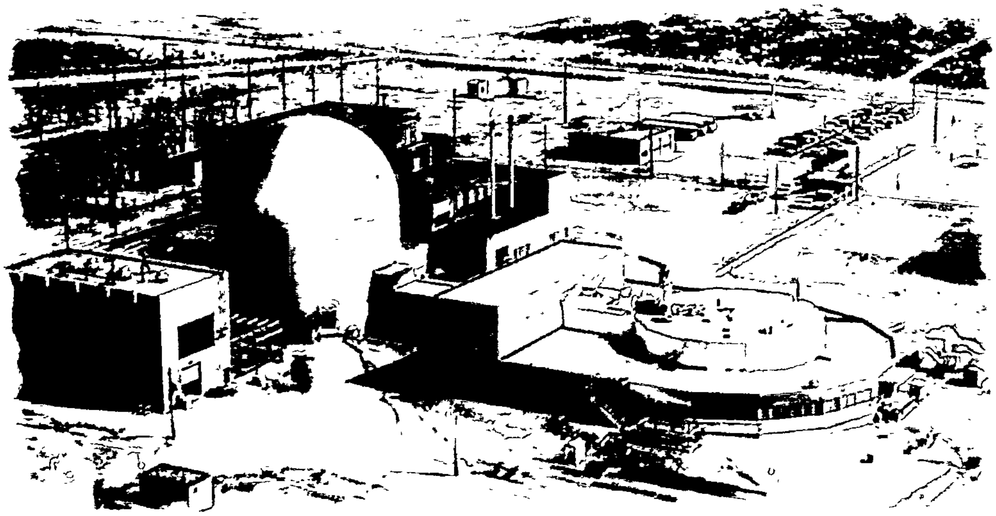
Work continued on waste processing as the incinerator proceeded to dispose of radioactive combustible wastes from the entire Laboratory. Some development studies also continued on a process for the recovery of waste aluminum nitrate solutions from the Redox process.

By the end of the 1940s, the Chemical Engineering Division had established its identity as a major part of ANL and had become recognized nationally for the originality and excellence of its contributions to nuclear technology. It had expanded both in personnel and in programs to the stage that larger quarters were necessary. The time was ripe to move on to the new buildings at the DuPage site.

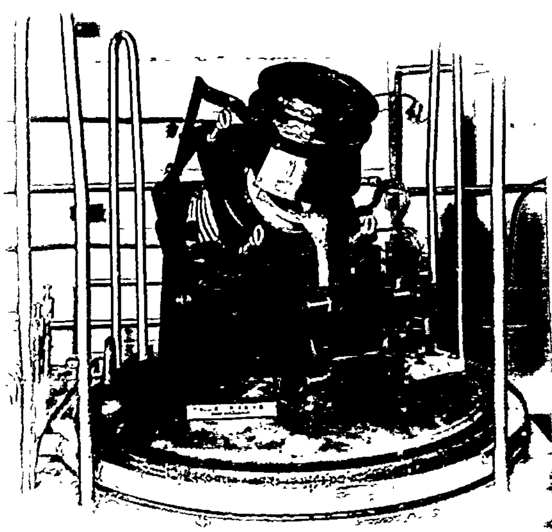
An attempt has been made to list in Table 1-4 all the people who worked in the Chemical Engineering Division during the 1940s.

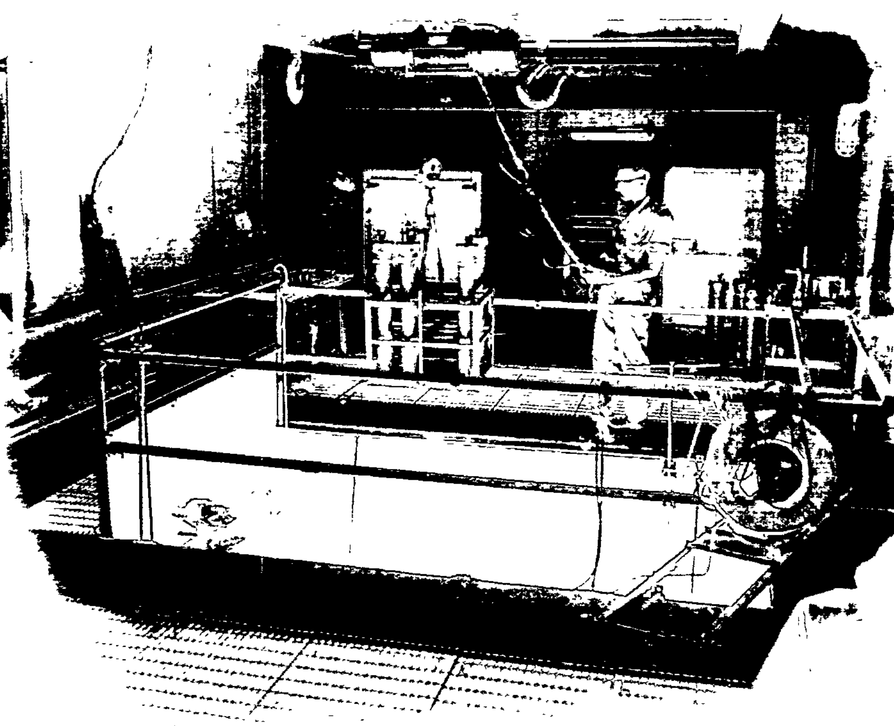
Table 1-4. CEN Personnel in the 1940s

Milt Ader	Cynthia Hall	John Natale
Alex Aikens	Don Hampson	Ed Peterson
George Asanovich	Gerry Harmon	Laurie Peterson
Eunice Banks	Eugene Hausman	Norma Pinches
Horace Baxman	Bob Hildebrand	Roy Post
Helen Bednarick	Jodi Hoekstra	Betty Reilly
Morrie Beederman	Myron Homa	Walt Rodger
Michael Berkman	Ed Hykan	Sy Rosenthal
George Bernstein	Herb Hyman	Laury Ross
Walt Blaedel	Dave Jacobson	Bob Schablaske
Aaron Boyd	Joe Jacobson	Karl Schoeneman
John Breeden	Al Jonke	John Schraidt
Jim Bresee	Bettye Kaplan	Wally Seefeldt
Herb Brown	Lou Kaplan	Chuck Seils
Les Burris	Alec Keday	Irv Shaffner
Artie Butschelder	Carolyn Kennedy	Art Shor
Jack Caster	Jim King	Charlie Stevenson
Norm Chellew	Milt Klein	Gladys Swope
Les Coleman	Corky Kloska	Virgil Trice
Virginia DeGrande	Doug Krause	Elton Turk
Lee Deutsch	Stephen Lawroski	Homer Tyler
Barry Devine	Henry Lee	Kegham Varteressian
Chester Deziehl	Milt Levenson	Richard Vogel
Ira Dillon	Norm Levitz	Sy Vogler
Les Dorsey	Harry Littmen	Bill Voss
Marie Driskell	John Loeding	Roberta Wagner
Harold Evans	Les Mandelstein	Matt Walling
Hal Feder	Larry Marek	Bill Walters
Olga Fineman	Asher Margolis	Elmo West
Phil Fineman	George Mason	Jackie Williams
Lee Gaumer	Lee Mead	Irv Winsch
Jim Gilbreath	Bill Mecham	George Yasui
Sherman Greenberg	Vic Munnecke	Marion Yoshioka



1950-1960: THE NUCLEAR PROMISE





1950-1960

(top) Experimental Breeder Reactor-II (domed structure) with close-coupled fuel cycle facility (right foreground) at the National Reactor Test Station in Idaho.

(bottom, left) Melt refining furnace in which uranium fuel is melted in a ceramic crucible, then poured into a graphite mold. This simple procedure removes fission products to an extent that the fuel can be refabricated and recycled to the reactor.

(bottom, right) The Gamma Irradiation Facility ("Swimming Pool"), located in Bldg. 310. This facility was used to evaluate the effects of gamma radiation on foods and various other materials.

2

1950-1960: The Nuclear Promise

The 1950s was a decade of exploration into new uses of atomic energy, mainly for the generation of electric power by public utilities. Several types of reactors were being considered. Much of the work at ANL was concerned with the potential use of breeder reactors as a long-range means of conserving natural uranium resources. The research and development effort by CEN on nuclear fuel reprocessing was expanded to include pyrometallurgical, fluoride volatility, and aqueous methods in order to accommodate the different types of fuels that might be used in the new types of reactors and to reduce the cost of reprocessing. The Division also broadened the scope of its activities to include other phases of the nuclear fuel cycle by initiating programs on feed materials processing and the treatment of radioactive wastes. Several other programs were started in areas such as the chemical aspects of reactor safety, fluidized bed technology, calorimetry, analytical chemistry research, and determinations of nuclear cross sections. The Geneva Conferences of 1955 and 1958 were particularly significant in that they marked the first large-scale exchange of information on nuclear technology among the nations of the world. A few CEN members also participated in the Symposium on the Reprocessing of Irradiated Fuels, which took place in Brussels, Belgium, in 1957.

THE NATIONAL AND INTERNATIONAL SCENE

Before turning to CEN in the 1950s, we briefly review some key national and world events that relate to the nuclear, reactor technology, and other work that was being done at the national laboratories during this period. Political, economic, and social issues, which are in a constant state of flux, have a major influence on the areas of investigation to be undertaken at the national laboratories and their levels of financial support.

According to some historians, the United States became involved in three new wars in 1950: (1) Vietnam, (2) Korea, and (3) the "Cold War" with the Soviet Union. The U.S. involvement in Vietnam at the time consisted only of sending a 35-man advisory group to assist the French in maintaining their colonial power in the country, but it did not develop into a shooting war until the 1960s. The Korean War, in contrast, began as a United Nations (U.N. "police action" when the North Korean Communist forces invaded South Korea, and it quickly escalated into an undeclared war. The U.N. forces under General Douglas MacArthur had managed to recapture most of the country when the Chinese Communists joined the North Koreans, forcing the U.N. troops to retreat to the 39th parallel. The conflict became a stalemate at the 39th parallel and an armistice was signed in 1953. The Korean War cost more than 54,000 American lives, and 40 years later we still face a belligerent North Korea threatening South Korea, possibly with nuclear weapons. Neither of these two wars had a direct impact on the activities of CEN, but they contributed to a general feeling of dismay in the country over the fact that the sacrifices of World War II had not ended our foreign problems.

The Soviet nuclear threat had become a matter of great concern and the arms race with the U.S.S.R. (the Cold War) was formalized in a National Research Council Report, NSC-58. The Soviets were obviously catching up with the U.S. in nuclear weaponry, and many individuals, including President Truman, felt that this could have happened only through extensive Soviet espionage. Recent information from the Soviet Union indicates a good deal of espionage had, indeed, occurred in the 1940s. Lavrenti Beria, head of the Soviet Secret Police (NKVD), and Igor Kurchatov, the Soviet physicist who supervised their nuclear weapons programs, had access to intelligence from espionage by Klaus Fuchs and others at Los Alamos which indicated that the bomb was possible and included other critical technical information. In 1950, the Americans discovered that Fuchs, a German physicist, who had become a British citizen and worked at Los Alamos, had passed along information from 1942 to 1949. He was sentenced to prison in England in 1950 and released in 1959, when he went to East Germany.

In 1948, Whittaker Chambers, an editor of *Time* magazine, and a former member of the Communist Party and Soviet agent in the 1930s, claimed that Alger Hiss, a former State Department employee, had given him State Department documents to be delivered to the Soviets. Hiss denied ever having known Chambers but he was indicted and served 44 months of a five-year sentence.

Another espionage case that attracted major attention was that of Julius and Ethel Rosenberg, who were accused of relaying vital information about the atomic bomb to Soviet agents. Ethel's brother, David Greenglass, a Los Alamos employee, who had supplied the information to the Rosenbergs, was sentenced to 15 years in prison. The Rosenbergs were sentenced to death and executed on June 19, 1953.

The Hiss and Rosenberg cases provided a springboard for Senator Joseph McCarthy to claim that the State Department was riddled with card-carrying Communists. He accused Presidents Roosevelt and Truman of 20 years of treason and denounced Gen. George C. Marshall. Even after Eisenhower was elected in 1952, McCarthy attacked large numbers of people, many from Hollywood and the news media, generally with unfounded charges. He finally met his match when he accused the U.S. Army of Communist penetration. Joseph Welch, the Army attorney, demolished McCarthy's credibility in widely televised hearings, and McCarthy was later censured by the U.S. Senate.

In 1952, Dwight Eisenhower defeated Adlai Stevenson in a race for the U.S. presidency. The Republicans coined the campaign slogan, "I like Ike," which was so popular that it became part of a song in a Broadway stage production, *Fiorello.* Eisenhower appeared to have an ambivalent attitude toward nuclear energy. When he first took office, he was concerned about nuclear energy contributing to "creeping socialism," but his position shifted and in 1953 he introduced his "Atoms for Peace" program in a speech to the United Nations. During the early 1950s, interest began to develop in commercial nuclear power as an outgrowth of the naval propulsion program, and the AEC became serious about power production. The McMahon Bill was revised in 1954 to: (1) provide for the development of nuclear power by industry, (2) permit international nuclear cooperation, and (3) relax the security requirements somewhat.

Prior to this act, the security classifications had been the same as those in the military: Official Use Only, Restricted, Confidential, Secret, and Top Secret. The McMahon revision provided for the "Restricted Data" classification, and the "L" clearance was instituted as a new category below the "Q" level. When the AEC was formed, AEC and military security clearances were separate and non-interchangeable and that continues to be the policy.

The first U.S. thermonuclear device was exploded in 1952, and the Soviets followed in 1953. Joseph Stalin died on March 6, 1953 and was replaced by Nikita Khrushchev, but this event had little effect on the arms race. The U.S. conducted many nuclear weapons tests, most of them in secret, in the 1950s, particularly in 1957-58. Only very recently (in 1994) was full information on the extent and types of these tests declassified on the authority of Hazel O'Leary, Secretary of the Department of Energy (DOE).

In 1957, the Soviets launched the first ICBM, followed closely by three Sputnik satellites. The U.S. news media became almost hysterical and began making much of the "missile gap." An attempt was made to revamp the educational system with the "New Math" and other innovations, but students and parents alike seemed more confused than edified by the abstract concepts that were being offered, and most of the new approach died out in a few years. Also in 1957, the nuclear-powered aircraft program was given a boost because the U.S. thought the Soviets had one, but that was finally discontinued in 1961, mainly because of shielding, weight, and safety problems. The missile gap fears were alleviated somewhat when the U.S. launched its first satellite, Explorer I, in 1958.

Antinuclear sentiment had begun to develop in the 1950s as a result of tests conducted by the military in the 1940s. United States servicemen had been allowed radiation doses up to 20 R, and some Pacific island natives had received exposures as high as 175 R. In 1957, Ralph Lapp wrote the *Voyage of the Lucky Dragon,* and nuclear doomsday movies such as *On the Beach* began to appear. The symbol,

was adopted by the antinuclear activists in 1958 as the "peace sign." It is based on the semaphore signal code wherein the two diagonal lines in the lower half of the circle represent the letter "N" and the vertical one is "D"—thus, "nuclear disarmament."

The AEC was required to hold hearings on the dangers of fallout in 1957. The first organized interventions in nuclear licensing hearings took place when Detroit Edison along with 20 other firms which had formed the Power Reactor Development Corporation (PRDC) proposed the Fermi I reactor near Detroit. This was to be a 60-MW fast breeder to produce power for Detroit and plutonium for the AEC. Union Leader Walter Reuther and the United Auto Workers were particularly active in these protests. The meltdown of the second core loading in ANL's EBR-I (see next section) was cited repeatedly.

About this time, at the request of the Joint Committee on Atomic Energy (JCAE), Brookhaven generated WASH-740, a study of the potential effects of a nuclear reactor accident. The news media exaggerated the worst and ignored the near-zero probability of such an event. Soon thereafter, the University of Michigan published a report that was even scarier. The insurance concerns raised by these and other studies culminated in the Price-Anderson Act of 1957, which limits the liability of utilities operating nuclear power plants. The JCAE was a strong advocate of civilian nuclear power, and several of the members became quite knowledgeable about the subject. Melvin Price, a congressman from the East St. Louis area in Illinois, was particularly active; he served as chairman of the JCAE for a period of time and was a co-sponsor of the Price-Anderson bill. He was acquainted with Admiral Rickover and was friendly toward Argonne.

In spite of the various problems and protests, an aura of optimism prevailed at the end of the 1950s about the future of civilian nuclear power.

REACTORS

Argonne was in the forefront of reactor development in the early 1950s. Reactor physics experiments were continuing in CP-3'. In 1954, CP-5, which was started up at the DuPage site, became a workhorse for users both within ANL and from outside the Laboratory. Various divisions of the Laboratory were also doing work related to outside reactor development efforts such as the Naval Propulsion Program.

The most innovative program, however, was the ANL work on fast breeder reactors. The first one was EBR-I, which was located in the Idaho desert at the National Reactor Test Station (NRTS). The EBR-I program had two major objectives: to demonstrate the feasibility of power generation and to demonstrate breeding, *i.e.*, a breeding ratio of 1 or higher. Three different cores were used in EBR-I, and the coolant was the sodium-potassium eutectic (known as NaK, pronounced like "knack"). This coolant was used instead of sodium alone because it is a liquid at room temperature (eutectic at -12.7°C, 9.1°F), which makes it easier to handle. An interesting innovation in the EBR-I reactors was the use of electromagnetic pumps for the NaK coolant, which avoided moving parts such as bearings in the liquid metal. They were backed up with mechanical pumps on standby as a safety measure, but proved to be highly satisfactory and were used as the normal operating mode. The three versions of EBR-I are listed in Table 2-1.

The generation of useful electrical power from the atom for the first time on December 22, 1951, was a major milestone in the history of nuclear technology. The fact that this was done in the Mark I version of EBR-I, the first fast breeder reactor, made the feat even more remarkable. The Mark I version was operated for about four years, during which time 4,000 MWh of heat was produced.

The Mark I core had metallic uranium fuel pins and stainless steel cladding, which are incompatible when in direct contact because they form a low-melting eutectic. To avoid this problem, NaK was used in the annulus to separate the two materials but still provide good heat transfer. The Mark I fuel elements were separated by 120° horizontal ribs in the cladding; these were eliminated in the Mark II core. The Mark II core was self-regulating under normal conditions, but instabilities were noted in transient tests, and in a test at high core temperatures and a short reactor period, a partial meltdown occurred on November 29, 1955, probably due to bowing of the fuel pins.

Table 2-1. Versions of EBR-I

Version	Fuel	Blanket	Cladding	Power
Mark I	93.5% Enriched Uranium	Natural Uranium	Stainless Steel	200 kW(e)
Mark II	93.5% Enriched Uranium	Natural Uranium	Stainless Steel	200 kW(e)
Mark III	93.5% Enriched U-2% Zirconium	Natural U-2% Zirconium	Zircaloy	200 kW(e)

Approximately one-third of the core was melted in the interior region; the fuel pins in the outer portions of the core and those in the blanket remained intact. Although this was a relatively minor event in a severe reactor test, the antinuclear activists viewed it with great alarm in the following years when they were protesting the proposed Fermi reactor. The Mark III loading used zirconium as a stabilizing element for the fuel and Zircaloy, an alloy with a higher melting temperature, for the cladding.

The Chemical Engineering Division was given the responsibility of determining whether or not breeding had actually occurred in the EBR-I reactor, and found that it had by a small margin, which proved the principle. These "proof of breeding" experiments are discussed later.

As shown below in Table 2-2, Argonne designed, built, and operated several experimental boiling water reactors (BWRs) during the 1950s, primarily for safety studies.

The ALPR (Argonne Low Power Reactor) was part of an Army reactor-development program. It was designed as a prototype of a packaged power plant that could be used in remote areas. The fuel was an enriched uranium-aluminum alloy; light water served as the moderator and coolant. The reactor could produce 300 kW of electrical power and 400 kW of space heat.

The BORAX reactors were used to investigate some of the safety aspects of boiling water reactors. BORAX-I had a small core of fully enriched uranium-aluminum alloy fuel plates clad with aluminum, and cooling was provided by natural circulation of water. The steam bubbles caused no instabilities and the system was inherently stable under transients. It was finally destroyed intentionally in a simulated "runaway" test in 1953, which caused a small steam explosion. BORAX-II, operated in 1954, was a larger version of BORAX-I. BORAX-III showed that turbine contamination by the steam was not a problem, but it was most remembered by the fact that it was used to light up the town of Arco, Idaho, on July 17, 1958. In 1956, BORAX-IV was operated with a thorium-uranium oxide fuel mixture. BORAX-V, in 1962, demonstrated the capability for supplying a conventional turbine with superheated steam. Argonne continued on with several other BORAX-type experiments to study various aspects of boiling water reactors.

Table 2-2. Argonne Boiling Water Reactors in the 1950s

Reactor	Power	Type	Location	Mission
ALPR	3 MW(t)	BWR	NRTS	Army Program
BORAX-I	1,200 kW(t)	BWR	NRTS	Safety Studies
BORAX-II	6,400 kW(t)	BWR	NRTS	Safety Studies
BORAX-III	12 MW(t)	BWR	NRTS	Safety Studies
BORAX-IV	20.5 MW(t)	BWR	NRTS	Safety Studies
BORAX-V		BWR	NRTS	Safety Studies
EBWR	20 MW(t) 5 MW(e)	BWR	DuPage	Small-Scale BWR Prototype

The BORAX studies culminated in construction of the Experimental Boiling Water Reactor (EBWR), which was a small prototype of a commercial boiling water reactor for commercial power generation. Located at the DuPage site, EBWR became operational in December 1956, and ran on the Commonwealth Edison network. After the demonstration, it was used in a joint ANL-Hanford Plutonium Recycle Program to obtain information on the use of plutonium as a fuel in light water reactors. In September 1965, EBWR began running at 70 MW, and then at 100 MW for a brief time, with plutonium as the principal fuel. It was shut down in 1967 when the mission was completed.

Another major ANL event in the 1950s was the beginning of construction work on the 12.5-BeV Zero Gradient Proton Synchroton (ZGS) on June 22, 1959.

The first nuclear-powered submarine, the U.S.S. *Nautilus*, was launched on January 21, 1954. The pressurized water reactor used in this vessel was based on ANL concepts and designs and was built under extremely stringent engineering specifications imposed by Admiral Rickover. Its performance was outstanding. It logged about 105,000 statute miles, mostly submerged, before the first refueling. About three years later, the Navy demonstrated the use of sodium-cooled reactor technology with the Sodium Intermediate Reactor (SIR), which was a prototype submarine propulsion reactor. This reactor, developed by the Knolls Atomic Power Laboratory (KAPL), was installed in the U.S.S. *Seawolf*, which operated from 1957 to 1959. The Navy abandoned this approach, however, after problems developed with sodium leakage into the *Seawolf's* steam reheaters. Construction of a nuclear-powered merchant ship, the N.S. *Savannah*, began in 1956. The ship was built and operated as a demonstration, but it generated little interest in the shipping industry or elsewhere. Now moored at Charleston, South Carolina, it is used as a museum. In 1959, the U.S.S.R. launched a nuclear powered icebreaker, the *Lenin*.

Rickover also had a major role in the construction of the Shippingport, Pennsylvania, pressurized water reactor, which was a joint project of the Duquesne Power & Light Co., Babcock & Wilcox Co., and Stone & Webster, Inc. This was the first civilian power reactor, and it operated from 1957 to 1982. A replica of its core was displayed at the Geneva Conference in 1958. Consolidated Edison, Inc., followed with the Indian Point reactor and the Commonwealth Edison Co. with Dresden-1. By the end of the 1950s, industry had developed a strong interest in nuclear power, and the Westinghouse Electric Co. offered the first guaranteed-price, turnkey power reactor.

In 1954, the first nuclear-generated electricity in the Soviet Union was produced by the 5-MW(e) Obninsk light-water, graphite-moderated reactor.

The 1950s were marred by two reactor accidents that were more significant than the EBR-I incident. In 1952, a meltdown and hydrogen explosion occurred in the NRX reactor at Chalk River, which is located in an isolated area in the Province of Ontario, Canada. The Chalk River reactor used natural uranium fuel with heavy water as the moderator. This proved to be more of a mess than a disaster; it was cleaned up and the reactor was back in operation in 14 months.

A more serious incident took place on October 8, 1957, when the British Windscale reactor, a graphite air-cooled thermal production reactor with aluminum-clad uranium fuel, caught fire, producing fallout in England and low, but detectable levels of radiation in France, Germany, and the Low Countries. Most of the public concern in England about this event was over iodine-131 contamination of cows' milk. The Wigner effect, a buildup of stored energy in graphite when it is irradiated by neutrons, was identified as the initiating factor in the temperature excursion that caused the fire.

In 1957, a very serious accident occurred at a nuclear weapons factory about 12 miles from the city of Kyshtym in the Ural Mountains. Over 10,000 people were forced to evacuate the contaminated area. For many years, the Soviets attempted to keep the event under wraps, but the rest of the world knew that something catastrophic had happened. It appears that a large quantity of nuclear waste material underwent a violent explosion, but there still seems to be some uncertainty as to whether it was caused by nuclear criticality, a chemical reaction, or both.

THE MOVE TO SITE D

When Site D was acquired for relocation of ANL, it consisted of about six square miles of land bounded roughly by Highway U.S. 66 (now I-55) on the north, Cass Avenue on the east, 91st Street and Bluff Road on the south and Lemont road on the west. The purpose of the large area was to create a buffer zone around the laboratory both for safety and security. In the early 1970s, several hundred acres of the land was made available as federal surplus property, and in 1973, under the Great Legacy of Parks Program, an additional 2,433 acres was transferred to the DuPage County Forest Preserve District, which added it to the Waterfall Glen Forest Preserve. The Argonne site now consists of about 1,700 acres.

Site D was created by purchasing properties from local farmers, along with the Freund estate, and consolidating them into a single entity. When the U.S. government acquired the land for Site D, it was removed from the DuPage County tax rolls because it was no longer private property. To compensate the DuPage County for this loss of income, the federal government has been making annual payments in lieu of taxes.

The land is generally flat, with some gently rolling areas, and is traversed by Sawmill Creek. A few magnificent old oak trees are in evidence. To enhance and preserve the property, a project was undertaken in 1953 to plant a million red, white, and jack pine trees, a formidable task that was completed in 1955. At present, much of the land is forested, with hardwoods and other deciduous trees thriving among the pines.

Everybody at Argonne is aware of the white deer. They came with the Freund estate, but their origin is uncertain. At one time there was concern that they might not survive because of disease, but they seem to have recovered and are thriving. The Argonne Guest Facility was opened in February 1958, and first-time visitors stepping out of the door in the morning were sometimes astonished to find themselves in the company of one or more all-white deer.

In the 1950s and for several following years, most of the buildings in the East Area were Quonset huts. This, along with the guard posts, exposed steam lines, and road layout, made the area look much like a WWII Army or Navy base. The 200 Area, with the new brick buildings around the inner circle, had more of a civilian campus character.

In 1950, the Chemical Engineering Division began to move to the DuPage site, starting with Bldg. D-310, and continuing with the major part of the move to the main building, D-205. Moving the site from Chicago to DuPage County made it necessary for nearly everybody to commute to work, as there was no public transportation to the Laboratory. This was a special problem for a few families, who, having lived in a large city all their lives, did not own a car and had not learned to drive. Many of the employees remained in Chicago, while others, especially the new people who were being brought on board, sought housing in the suburbs. For the first year or two, ANL operated a bus system with routes from Chicago and some of the suburbs to the Laboratory. Alice Graczyk sold the 35-cent tokens in her L-Wing office. One driver, in particular, on the Chicago-ANL bus, who was a ventriloquist, sometimes startled the passengers by opening and closing the door and making it sound as if somebody outside were yelling to get aboard. Another route, which went to Downers Grove, Lisle, and Naperville, had a regular passenger who sat in the back quietly strumming a guitar and singing Western ballads. In 1953, the ANL bus system became a casualty of budget cuts and was discontinued.

Most of the employees were relatively young (in their twenties and thirties) at that time and could not afford two cars, so car pools became popular. The optimum size for a car pool is a complex problem, and was the subject of much discussion. Viewed simply, a two-person pool should decrease an individual's driving by 50%, a three-person pool by 67%, *etc.*, and little additional benefit would result from going to four or five members, especially considering the additional time required to pick up and discharge everybody on both ends. Some pools had five members so a person would drive the same day each week. But then, one had to factor in the probability that somebody would be sick, on vacation or travel, or would oversleep or have a late meeting. Sometimes there were personality clashes. In spite of these problems, many established car pools have been operating for decades; they offer the opportunity for humor, gossip, relaxation, and technical discussions and have created many close friendships. They were a godsend during the fuel shortages of the 1970s.

When the Division moved to DuPage, Bill Mecham, a chemical engineer, owned a 1931 Rolls-Royce, which he drove to work. The windowsills of that large, black car were on about the same level as the roofs of the other cars in the north parking lot. Occasionally one could see Bill riding "high in the saddle" above the other cars as he cruised through the lot looking for an oversized parking place. He once mentioned a couple of "fender benders" he had had in the Hyde Park area with that car; according to Bill, it was the other cars' fenders that did all the bending.

The area surrounding Argonne in the 1950s was much less populated than it is now, and the only four-lane road was the legendary U.S. Route 66 at the north edge of the site. During heavy snows, the plowing was less efficient than it is now, and getting to work or back home could be chancy. On at least one occasion, Dr. Lawroski's car pool had to take shelter in a nearby farm-house on Lemont Road until the situation improved, and there were several times that many people didn't get back home until 9 or 10 p.m. because of heavy snow or freezing rain.

There are at least two CEN car pools that deserve longevity awards. One is the famous Park Forest pool, which, in 1953, consisted of Milt Ader, Hal Feder, Bob Larsen, Charlie Stevenson, and Martin Steindler. That car pool has functioned more than 40 years with various participants. According to some of its members at the time, riding with Feder, who had just learned to drive, was an unnerving experience. The other car pool of note was the one from Wheaton, consisting of Paul Nelson, Martin Kyle, Terry Johnson, and Les Coleman.

Most of the CEN employees began to seek housing in communities within a reasonable commuting distance from the Laboratory. These communities were a diverse lot. Many of them were located along the various commuter rail lines such as the Northwestern, Burlington, Illinois Central, and Santa Fe, which fan out from Chicago. Some of the communities were well established, others were smaller rural towns that were beginning to grow, and many were basically "bedroom communities" that had sprung up after WWII. Some of these communities were apprehensive about the large influx of Argonne employees, so the Laboratory sent out advance people to explain that these scientists and engineers generally behaved themselves, had been screened for criminal records, often went to church, and, most importantly, paid their bills on time. Some racial problems arose, but they eventually became defused.

Housing, especially rental apartments, was not easy to find, and the Laboratory assisted people who needed help. For those who were interested in buying property, the Laboratory provided the services of Byron Kilbourne, who was well-versed on the market and real estate values in the area, as well as the details and pitfalls of home construction. He would not normally seek out properties, but if an employee found one he thought he might want to buy, Kilbourne was most accommodating in going out and looking over the property and making a solid recommendation. He often did this several times for a particular individual. He was a tough evaluator, and frequently shattered a family's dreams about some house they had found, but one could be sure that any property and price he approved was a good deal. On one occasion, a potential buyer had his eye on a beautiful wooded lot in the Green Acres area of Naperville. Kilbourne looked it over and said, "Dig a hole a foot square and two feet deep, fill it with water and see how long it takes for it to drain away." The man dug the hole, came back the next morning to fill it with water, and found that it was already half full. The deal was off.

As the ANL employees moved into their new homes, their social lives tended to become more oriented toward their own communities. It wasn't long before many of them became involved with local community affairs. Many joined churches, service clubs such as the Jaycees, Kiwanis, or Rotary, or special interest groups, and some were active in school activities. Argonne people then started being appointed to various advisory groups or elected to public offices such as city councils, school boards, park district boards, and others. The suburbs all have a great need for coaches and officials to handle all the organized athletic programs for children, and many Argonne fathers became involved in these activities. Two future CEN division directors, Les Burris and Martin Steindler, served as school board presidents. Dr. Lawroski never ran for public office, but he achieved what is considered an even more prestigious position in Naperville. He was accepted into a small, elite group of individuals that included the current mayor and some other highly influential people in town. They had breakfast every morning at a downtown drugstore counter, each with a reserved stool. Within this group, he was known as "The Professor."

NEW EMPLOYEES

A new staff member coming into the Division in the 1950s was subjected to a more or less standard routine. For the chemists, the first assignment was to spend a few weeks in the Analytical Chemistry Laboratory. Doug Krause was in charge of that group, and Betty Reilly was the instructor. Betty was a good-natured, patient teacher, and this training experience was both pleasant and highly instructive. Many of the people had not dealt with radioactivity before, and this was an excellent introduction to handling hot materials and counting techniques. It also gave one a chance to become acquainted with the people who would be doing their analytical work later and to gain an appreciation for their problems. New staff employees were expected to participate in training courses on reactor technology or similar subjects that were being offered by the Laboratory from time to time. Newly hired laboratory technicians and operators were normally well-skilled, but required some on-the-job training to become familiar with the unique problems of dealing with radiation, security, and other specialized aspects of a nuclear research facility.

One of the most rewarding aspect of working in CEN was, and still is, an opportunity to interact with a wide variety of technical people both within and outside the specific group to which one was assigned. Sharing of ideas, techniques, and equipment among the various groups of the Division was extensive. There was also a lot of cooperation among the divisions of the Laboratory, especially during the development and construction of EBR-II and the Fuel Cycle Facility. Nearly the whole laboratory was involved in that project in one way or another. Over the years, CEN has had particularly close ties with the Reactor Engineering, Reactor Analysis and Safety, Chemistry, and Metallurgy Divisions. (Due to expansion in the scope of the work, the Metallurgy Division has a number of successors, including Solid State Science, Materials Science, Materials Components, and Energy Technology.)

There were also many interactions with the academic world. Several of the ANL staff members had come from teaching positions at universities. The Division had connections with departments at a number of universities, and many individuals, including some CEN members, completed the experimental part of their thesis work at ANL in a cooperative arrangement with a university. Opportunities were provided for students and faculty members to work in the various CEN programs on temporary assignments. The Division used consultants from university faculties when some particular expertise was needed. Staff personnel from CEN were occasionally invited to present seminars to university departments, sometimes in connection with recruiting trips. Staff members from CEN were often involved with various industrial organizations, some of which were potential customers for the technology that was being developed. An example of this was the UF_6 production plant that was built by the Allied Chemical Co. at Metropolis, Illinois. In some cases, the Division contracted with commercial firms to provide specialized services or equipment.

The CEN staff people frequently presented papers at national meetings of professional societies such as the American Institute of Chemical Engineers (AIChE), the American Chemical Society (ACS), the American Nuclear Society (ANS), and the Geneva Conferences. (Some of the first visitors to Europe came back home using the British pronunciation of "processes" and the French pronunciation of "centimeters"; a few were wearing berets.) Intersite visits to the other laboratories having similar interests were common, and topical meetings were arranged by the AEC in some cases. The people involved in particular areas of work, after a few years, seemed to develop a kind of camaraderie with their counterparts at other institutions both in the U.S. and overseas. These interactions extended to the technical staff at AEC Headquarters, with the result that they became personally acquainted with some of the CEN staff. An interesting aspect of these various interactions was that if one transferred to a different CEN program, the whole process was repeated. One had to not only become technically proficient in the new area, but also get acquainted with others doing related work both at ANL and in the outside world.

Everybody had to become familiar with the radiation safety rules and regulations and to learn how to use film badges, dosimeters, and monitoring instruments. Special safety shoes that were colored bright yellow were required when one was in the radiation areas of the building. It didn't happen at all frequently, but there were a few occasions when someone would be walking down a street in his town and suddenly realize to his horror that he had forgotten to change his shoes; it was hard to be inconspicuous. Although this was a technical violation of the safety rules and highly embarrassing, it didn't create a real hazard because all personnel had to check their feet to leave the building.

Because many of the CEN programs entailed work with radiation, urine samples were requested rather frequently for bioassay purposes. Empty sample bottles were provided for the individual to take home overnight and bring back full in the morning, when they would be picked up. The containers for these sample bottles were identical to the black metal lunch boxes that were used by quite a few people who brought their lunch to work. There are undocumented rumors that such boxes have been accidentally switched on occasion, with the result that the bioassay lab received a ham sandwich and the worker found a bottle of urine for his lunch. There was one instance in which a new employee received his first request for a urine sample during a certain week. His understanding of the instruction was that they meant every day of that week; the Division had a call from Bioassay, asking that the nature of their request be explained to him more clearly.

Safety has always been a paramount concern in CEN. John Schraidt was the first Division Safety Officer, and he took the job seriously. Anybody who was caught twice without safety glasses in the laboratory was threatened with dismissal. New employees were trained to use the different types of fire extinguishers, fire blankets, safety showers, self-contained breathing apparatus, eyewash fountains, and other safety equipment. Instructions were given on "Dial 13" (now "911") emergency line. A fire brigade was set up to handle emergency situations in the building, and a safety committee with a rotating membership was organized to conduct routine safety inspections throughout the building. A special committee was appointed to review any new experimental setups and procedures for potential hazards and to develop preventive measures if necessary. Safety information and directives were provided to staff members continuously by the AEC, the Laboratory, and the Division. The scope of the safety activities is far too large to be described here, but the above-mentioned practices are still in effect, and they have proved their value over the years. The Division has received numerous commendations for large numbers of man-hours worked without a disabling injury. During one period of time, all employees were presented with rather nice gifts, such as card tables, hand lanterns, and home fire extinguishers when the Division had completed a certain number of employee-years without a lost-time accident.

Fig. 2-1. John Schraidt

Security was another important element in the training of new employees. In the 1950s, practically everything a staff member did was classified as secret. All the experimental procedures and results were to be entered into secret notebooks, with each page signed by the investigator and witnessed by two other individuals who had either observed the experiment or would state that they had read and understood the results. The regular CEN progress reports, as well as the internal weekly or monthly reports, were secret. Reports on most of the individual investigations, however, could be sent to Hoylande Young, the Director of Technical Information, where they were cleared for publication in the open literature or presentation at a meeting. Dr. Young, who had a Ph.D. in chemistry and had worked as a Senior Chemist on the plutonium project in the Met Lab, was always most cooperative in expediting the declassification process and suggesting changes if they were necessary.

The fact that the offices were usually occupied by three staff members who shared a file cabinet with a combination lock created some problems. The file was to be locked when nobody was in the office, but when people left for the day there was sometimes a slip-up that resulted in a security violation. The night security officer, not knowing who was the culprit, would arbitrarily put down any one of the occupants' names. On a few occasions, some new employee, usually a chemist, would convert the three numbers of the file combination to symbols for the elements of those atomic numbers and write them down in some inconspicuous place. The guards had that one down pat; they could read the periodic table as well as anybody else, and that was a sure way to get a violation. The punishments for a security violation varied. One might be summoned for an interview with the division director to explain why the file was not locked. Forgetfulness was not a good answer, nor was there much of anything else one could say that would be very convincing. In fact, there was usually a good chance that you were not the guilty party, but you couldn't be sure. It was a bit like explaining to your wife why you locked her keys in her car—there was no good answer. Another punishment that was invoked on occasion was a week's assignment to go through all the offices in the building at the end of the day and make sure that everybody's file was locked. If an employee developed a pattern of repeated violations, it became a serious problem.

On February 5, 1951, the nationally known radio commentator and newspaper columnist, Paul Harvey, decided to get a scoop on Argonne's lax security measures by climbing over the fence along the outer perimeter of the laboratory site. Unfortunately for him, the security force was there to greet him, and the Chicago media had a ball with the story. When Bldg. 205 was first occupied, there was an 8-foot perimeter fence around the building, and the only access was through a single guard post. Evidence of that guard post still remains in the form of the concrete steps with iron railings at the south end of the north parking lot. Later on, for a period of time, a guard was posted in the Bldg. 205 lobby. The Physics Building (D-203) and the CP-5 reactor were declassified in 1953, followed by the Chemistry Building (D-200) in 1955.

One of the responsibilities of the security guards was to patrol the buildings at night to assure the physical security of the building, and also to watch for any problems in the laboratory areas. The most common problem by far was with cooling water lines that had lost their integrity for one reason or another, causing flooding of the area. Names and phone numbers of workers responsible for each lab were posted on the door, and almost every scientist or engineer who was doing laboratory work in those days has probably had at least one of those unnerving, middle-of-the-night phone calls from a frantic security man asking what he should do. If it was your own equipment, you could usually tell him over the phone how to shut it down safely (such as turning off a furnace before the cooling water supply). Often it was somebody else's equipment and you would know who should be called, but on some occasions it was necessary to jump into your car, race out to ANL and try to cope with the situation.

SERVICES

A wide variety of supporting services was, and still is, available to Laboratory employees. Radiation Safety was one of the most important ones. Everybody was required to wear dosimeters and film badges, which were read by the Radiation Safety personnel. They had many other duties, surveying laboratories and equipment, checking items going out of the building, maintaining the hand-and-foot counters, providing advice and assistance in the design and operation of equipment, surveying wastes—to name a few. The radiation safety personnel were not members of CEN, but they tended to have long assignments to particular buildings and became regarded as co-workers. Some of the "Health Physics" personnel most closely connected with the Division in the early days included Ken Woods, Walt Smith, Ted Allen, and Frank Marchetti.

Another service was the Travel Office, which was a little different in the early 1950s than it is now. On the travel request, one had the choice of rail or air transportation. Train travel was still used widely, although flying was rapidly becoming the mode of choice. The trains had not been improved a great deal after WWII, and some of them were still pulled by steam locomotives. One particularly quaint train was the Long Island Railroad route from New York City to Patchogue, New York, which was the normal destination for a Brookhaven visit. Air conditioning was not universal. Many CEN people made long train trips to destinations such as the Idaho site, Hanford, Los Alamos, Oak Ridge, and Washington, D.C. The Laboratory would provide normal Pullman accommodations on a train, but those in the know usually contributed a small amount of their own money to get a double bedroom. One of those trips, together with a meeting, could easily occupy a week or longer, but it did provide extra time to work on a presentation. The planes were propeller models (DC-3, DC-6), slow and noisy by present-day standards, and they served each passenger a small package of cigarettes with the meals. Some employees, including Walt Rodger, who felt that flying was an unnatural act for a human being, refused to have anything to do with it. (Surprisingly, some years later Walt became a private flying enthusiast.) Rental cars had not yet become commonplace, so people depended on taxis and local public transport systems.

All the air travel was out of Midway Airport until O'Hare was completed in the mid-1950s. Transportation between one's home or the Laboratory and the airport was by government car with an Argonne driver. Those drivers seemed to know everybody at ANL. Their relationship with the Chicago police at O'Hare was interesting. The police officers were in the habit of whacking the fenders of cars with their nightsticks to keep the traffic moving, but they apparently suspected that this might not be advisable for a U.S. Government car. The cars also met the arriving ANL passengers on the upper (departure) deck at O'Hare, a practice that could earn the average driver a traffic ticket.

Originally, the only cafeteria was in Building 2 in the East Area. For many people, bringing their own lunch was more convenient because of the distance to the East Area, which required riding a shuttle bus. There were few restaurants in the surrounding area at that time. In addition, engineering projects at the time were frequently operated around the clock. For these reasons, a cool room for the storage of lunches was provided near the lobby of Bldg. 205. An additional cafeteria, which was installed in Bldg. 203 where the Central Library is now, was better situated for Bldg. 205 occupants. Finally, several years later, a new cafeteria (Bldg. D-213) was built to serve the entire laboratory. The cafeterias were operated by ANL, rather than by an outside contractor as is the case now. A lunch consisting of an entree, two side dishes, and a roll was 65 cents in the 1950s.

For those who did "brown bag" it, Building 205 had a large, attractive lunchroom on the second floor of L-Wing. Bridge, pinochle, and chess games were popular at lunchtime. One particularly cutthroat bridge group consisted of Al Glassner, Bob Larsen, and Hal Feder plus anybody else they could nail for a fourth. Some individuals, notably Walt Rodger, John Loeding, and John Schraidt, were famous for their gargantuan lunches, which consisted of three or four full-size sandwiches along with the usual fruit and dessert. None of them seemed to gain any excessive weight. The 205 lunchroom could be opened up to a large conference room, and this arrangement was used a few years for the traditional CEN Christmas parties, which were lively affairs. In 1953, the Laboratory Director imposed a definite ban on alcohol at such parties. The 1954 party was a more somber affair, the main entertainment being a cake-decorating demonstration by Bill Sovereign, whose family operated a bakery in Naperville. The Christmas parties were later moved off site, and then, some years later, they were returned to the building in the form of a potluck luncheon and some entertainment. Annual CEN picnics were instituted and proved to be highly successful because families, as well as the employees, were invited, and Argonne Park had the facilities for games and other activities. Eventually, the lunchroom was relocated to the service floor where it is now.

Nearly all the experimental work at CEN required the services of designers, draftsmen, machinists, and, to a lesser extent, glassblowers. The technicians and staff personnel could handle the more mundane work of this type, but real expertise was needed for many of the projects. In the early 1950s, Bill Voss and Tom Denst were full-time machinists who worked for CEN although they were officially a part of Central Shops. These artisans tended to be a bit stand-offish and gruff at times with a new staff member until they had a chance to size him or her up. If the new person was reasonable and appreciative of their work, however, things would work out well, and after a few months they would knock themselves out to be helpful. If asked, the machinists would often contribute ideas during the design stage of a piece of equipment that would make it easier to fabricate and use. In the early days, most of the glass blowing was done in the Chemistry Division, and any specialized work was sent to Central Shops. Later on, Bill Schulze, a professional glass blower, took care of the Division's needs, and performed several other important functions, including the coffee facility. John Schraidt was in charge of the design work and was extremely helpful in working with the staff on their equipment designs. Dick Malecha and Johan Graae, on assignment from Central Shops, were also responsible for much of the design work and made major contributions to the equipment and facilities available to CEN. Dick later became a member of CEN. Harry Smith, a pleasant, cooperative individual, was the head draftsman; he also was most helpful in arranging for drawings that were required for the shop work and other purposes.

Special Materials was another organization that interacted closely with CEN. Then, as now, all fissile and fertile materials, including uranium, plutonium, and thorium, were logged in when received, and a careful accounting similar to financial bookkeeping was required throughout their use until the time they were returned to the Special Materials Division. Other nuclear-related and expensive materials such as beryllium, zirconium, and platinum were subject to similar accounting and auditing. In many cases, the group leader was held responsible for all the special materials used by the group in order to simplify the bookkeeping.

The Division had a limited library when it occupied the new building. A technical records room with a vault for classified materials was situated on the second floor of L-Wing, but one had to use the Chemistry Division library in Bldg. 200 or the Central Library for access to most journals and reference books. It was rumored for a long time that one of the items in the vault was a pre-war issue of the *Saturday Evening Post*, which had an article about the possibility of a nuclear weapon with enough technical veracity that it was recalled by the government and classified secret. Since that time the CEN Library has grown much larger, and has had to move several times to accommodate that growth. It finally evolved into a permanent, attractive, and well-equipped facility at the east end of L-Wing. Augustella Thompson was the librarian for many years. She also managed the classified document room. In recent years, this function has been ably performed by Sharon Clark, Paulette Windsor, and others.

The Division has always enjoyed an excellent reputation with respect to the quality of its progress reports and other publications. That stems primarily from the quality of the work done by the staff and leadership of the management, but much credit is due to the technical editors. Joe Royal was hired as the first full-time technical editor and he set high standards. He was not a "blue pencil" editor. Instead, he flagged items with numbers keyed to a list of questions and comments that sometimes exceeded the length of the manuscript, but they were always germane and often educational. Joe, who at one time was associated with the Met Lab, came to CEN from the American Medical Association. He had a Ph.D. in chemistry from Berkeley and was able to comment cogently on the technical content, as well as the writing. Prior to Joe's arrival, the associate division directors were doing most of the final technical editing. The technical editors not only ensured that the Division produced high-quality writing, but also improved the writing skills of the staff through their extensive comments and conversations. Several other people have served in the Technical Editing Group, both under Joe and later on, including Tom Cramer, John Simmons, Gwen Kesser, and Susan Barr. In addition to the Division technical editors, some of the larger groups had their own editors to help with the workload. Among these individuals were Sy Vogler, Milt Ader, Jack Arntzen, and Ellen Hathaway. In more recent times, this tradition of excellence has continued under the direction of the current Division editor, Joe Harmon. Maria Contos has made a major contribution in organizing, compiling, and documenting lists of almost all the Division's publications since its inception.

For a short period of time after the Division moved into Bldg. 205, a full-time nurse was available on the premises. It turned out that she had little to do other than dispensing an occasional Band-Aid® or aspirin, so that service was dropped. Everybody was required to take the annual physicals, and all injuries, no matter how minor, were to be handled by Health Services. If an individual working in a hot lab had even a minor cut, it was checked for radioactive contamination. On one occasion, Bob Larsen nicked his finger slightly while working in a plutonium glove box, and the Health Division found no contamination but suggested that he should wear a finger cot for a few days just as a precaution. He told them that he couldn't do that because he was a Catholic.

The other services available to the employees, such as Graphic Arts, the Credit Union, Procurement, and others were much the same as they are now. Lee Mead, a big genial man who had previously been a guard at the Met Lab, was in charge of procurement, assisted by Marie Driskell, who always seemed to be on the paging system.

TOOLS OF THE TRADE

Considering that William Shockley and his co-workers invented the transistor in 1948, it is not surprising that solid-state electronic devices were unheard of in the early 1950s. Calculations were usually done with slide rules, nomographs, electromechanical desk calculators (Frieden, Marchant and Monroe were popular brands), or published tables of logarithms and other functions. (Many of those tables had been generated or updated by unemployed mathematicians under the WPA program during the Great Depression.) Ward Hubbard, who was raised in China, occasionally used an abacus and was proficient with it, but that didn't seem to catch on with the other staff people. One salutary effect of the slide rule was that it usually couldn't generate more significant figures than the data warranted. Anybody who has not shared an office with someone doing a least squares fit with one of those noisy electromechanical calculators cannot fully appreciate the term "grinding out data." The Division management was reluctant to purchase additional calculators, the attitude being that the "real" work was done in the laboratory and computations were a minor aspect of the research. Another factor leading to this reluctance was a concern that a large investment might be wasted on a system that could become obsolete almost overnight. Irv Johnson recalls, "Ward Hubbard and I had to scheme to get a Frieden calculator for our joint use. Ward was able to salvage a worn-out calculator that an accounting office had thrown away. After having it serviced at least once a week, Dr. Vogel finally gave in and allowed us to purchase a new Frieden."

Argonne was one of the national leaders in computer research and development. On January 28, 1953, members of the Physics Division completed their first electronic digital computer, the AVIDAC (Argonne's Version of the Institute's Digital Automatic Computer). Patterned after a machine at Princeton Institute, it cost $250,000, and used 2,500 vacuum tubes, 8,000 resistors, and 3.5 miles of wire. The memory consisted of electric charges on the inside face of a cathode-ray tube and required continuous renewal. The following September, this group completed the ORACLE, a similar, but larger machine to be used at Oak Ridge. It cost $350,000, and had 3,500 tubes, 20,000 resistors, 7 miles of wire, and a cathode-ray-tube memory. One can't help but suspect that the name of the machine, Oak Ridge Automatic Computer Logical Engine, was conjured up to fit the acronym. These early machines, although very useful and remarkable for their time, didn't begin to approach the capabilities of today's ordinary desktop computer. Computer technology advanced rapidly in the 1950s, however, and the reactor engineers began using the Univac machine routinely. By about 1960, ANL had obtained large mainframe digital computers from IBM. As an interesting sidelight, a number of analog computers were built at ANL; these were excellent simulators for reactor control systems and were adapted for reactor operator training. Lou Baker and his group used the PACE analog computer at the Applied Mathematics Division (AMD) for some early theoretical calculations in the metal-water reaction program.

It was only near the end of the 1950s that CEN personnel began to use the central computer facilities in AMD. The procedure for having a job done was first to explain the required computation exactly to an AMD programmer, who would then write the program and develop a set of data forms, which were sometimes rather arcane. The completed forms would be submitted to AMD (with the cost code) and the results would eventually be printed out. This entailed a lot of running back and forth between Buildings 205 and 221; Dean Pierce brought an old "beater" bicycle to ANL expressly for this purpose. At about this time, several CEN people began to take courses in programming languages (mostly Fortran) so they could write their own programs. It was not until the 1960s, though, that the use of computers by CEN personnel began to flourish.

The use of computers in conjunction with experimental equipment was much the same. Carl Crouthamel's group, who employed 256-channel analyzers to sort out gamma-ray spectra, was one of the earliest to use computers in conjunction with experimental equipment. This whole room was full of electronics, mainly vacuum tubes.

The situation was much the same with laboratory equipment. There were no integrated circuit devices or electronic digital readouts. Chemists used the classical two-pan balances that required averaging of several swings of the pointer around zero. Temperatures were usually determined with thermometers, by measuring a thermocouple output with a portable (usually Leeds & Northrup Type K®) potentiometer or with a strip-chart recorder. Platinum resistance thermometers were used for high-precision temperature measurements. Oscilloscopes were available, but were primitive by today's standards. Bill Olsen had an instrument shop and storage area on the service floor. Bill was a cooperative individual, and through a combination of doing repairs and shuffling equipment around as needed, he helped many programs through crises.

There is probably still enough vintage equipment around the building to create a small museum; one cannot help but admire the beauty and craftsmanship of some of that old laboratory equipment. Its polished brass and wood had much more esthetic appeal than the gray or beige plastic and metal housings that are now in vogue.

There is probably no one group of people who have benefited more from the technical advancements of the last 40 or 50 years than the secretaries and administrative personnel. Fortunately, changing an old-fashioned typewriter ribbon is now a lost art, although it did offer the young men an occasional chance to perform a gallant act for one of the secretaries, who could most likely have done it faster and better herself. Duplication was by mimeograph or carbon copies (we still see "cc" occasionally on distribution lists produced by a laser printer). Ditto® then came into general use, and, although more convenient than mimeograph, it was still messy and corrections were a pain in the neck. Purple fingers were the norm with the secretarial staff, and if they weren't careful, it wasn't necessarily confined to the fingers. To check typos, one person read the material aloud while another one checked the text. The only spelling checker was the dictionary. The secretaries had to learn a lot of technical terms and jargon. Dictaphones were available, but not generally used by the technical staff. Almost everything was transcribed from handwritten material, much of which was nearly illegible. It was not uncommon for someone to take a hand-written note to the writer's secretary to have it translated. Manual typewriters began to be replaced by electric models, but it was not until the 1960s that the IBM Selectric® typewriter became available. It was popular because of the ease of use and the capability for different fonts by changing the type balls, which some found, to their dismay, were quite fragile. Finally, to add to the problems, nearly all the material a secretary typed in those days was classified and had to be handled as such. The ubiquitous ballpoint pen, which now seems to have been around forever, was introduced to the general public with considerable fanfare in the 1950s, a major claim being that it could write under water.

In the administrative areas, there were a variety of electromechanical "business machines" such as the Addressograph®, which fulfilled the needs of the payroll, accounting, and other such groups. These, too, were ripe for change to the electronic age.

THE NEW BUILDINGS

Building D-205

Building D-205 was constructed during the period 1949-1950 (Fig. 2-2). The architect-engineer firm was Voorhees, Walker, Foley, and Smith of New York City, and the layout and design were developed primarily by Steve Lawroski, Charlie Stevenson, John Schraidt,

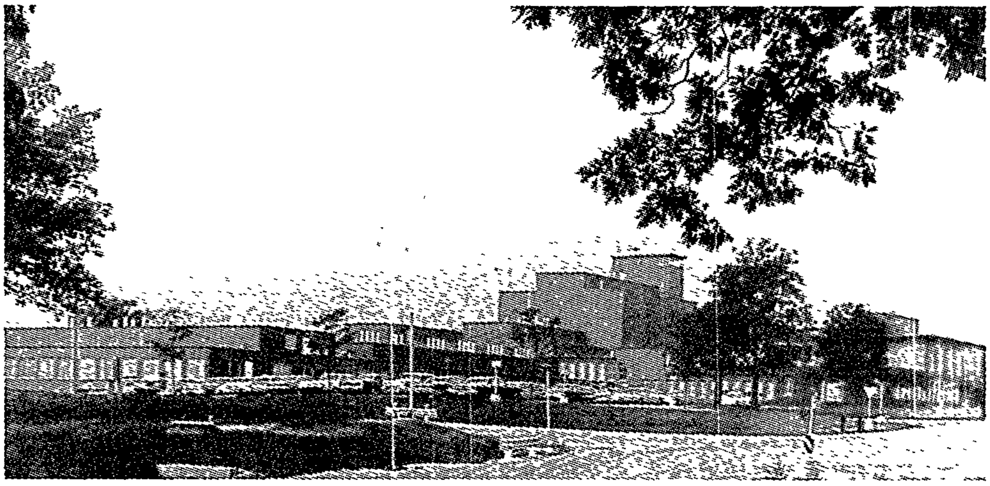


Fig. 2-2. Building 205

and Ed Peterson. A plan of the building as it now exists is shown in Fig. 2-3. The original structure did not include the following, which were added in the years indicated:

1. The Senior Cave (K-Wing) in 1956.
2. X and W Wings plus the extensions of A and B Wings in 1961-62.
3. Y-Wing in 1975-76.
4. Environmental Testing Annex in 1982.

Otherwise, the building was much as it is now.

When Building 205 was first occupied, the administrative functions were mostly in L-Wing, which was laid out somewhat differently than it is at present. Figure 2-4 shows the original plan of L-Wing as one entered the building from the north through the front doors. On the ground floor, the Division Director's office, occupied by Dr. Lawroski, was at the northeast corner. Charlie Stevenson, the Associate Director, and secretaries Virginia DeGrande, Evelyn Rafacz, and Florence O'Neil were in the adjoining offices. A conference room and an area containing the mailroom and space for stationery supplies and duplicating equipment were across the hall. The offices in the west part of L-Wing were occupied by other CEN administrative and management personnel, secretary Alice Graczyk, a Special Materials office, the Site Administrator (Ed Peterson), and a design group consisting of John Schraidt, Johan Graae, and Dick Malecha. Across the hall was a drafting room, with Harry Smith in charge, and the washrooms. The upper level of L-Wing had a large conference room with a folding partition that could be opened up to a spacious lunchroom with limited service facilities. West of the conference room was a technical records room, which was a forerunner of the CEN library, and a vault for classified materials.

For many years, most of the CEN administrative offices were relocated to A- and C- Wings, and L-Wing was rearranged and occupied by the ANL administration and various other groups, depending on the relative space requirements of the organizations. As the Division expanded with larger and more diverse programs, so did the need for more extensive design and drafting space. As a consequence, the upper level L-Wing lunchroom with its large area and excellent natural lighting was converted into a drafting room.

At one time, Robert Laney, the Associate Laboratory Director, and his staff occupied L-Wing and Room L-252 became known as

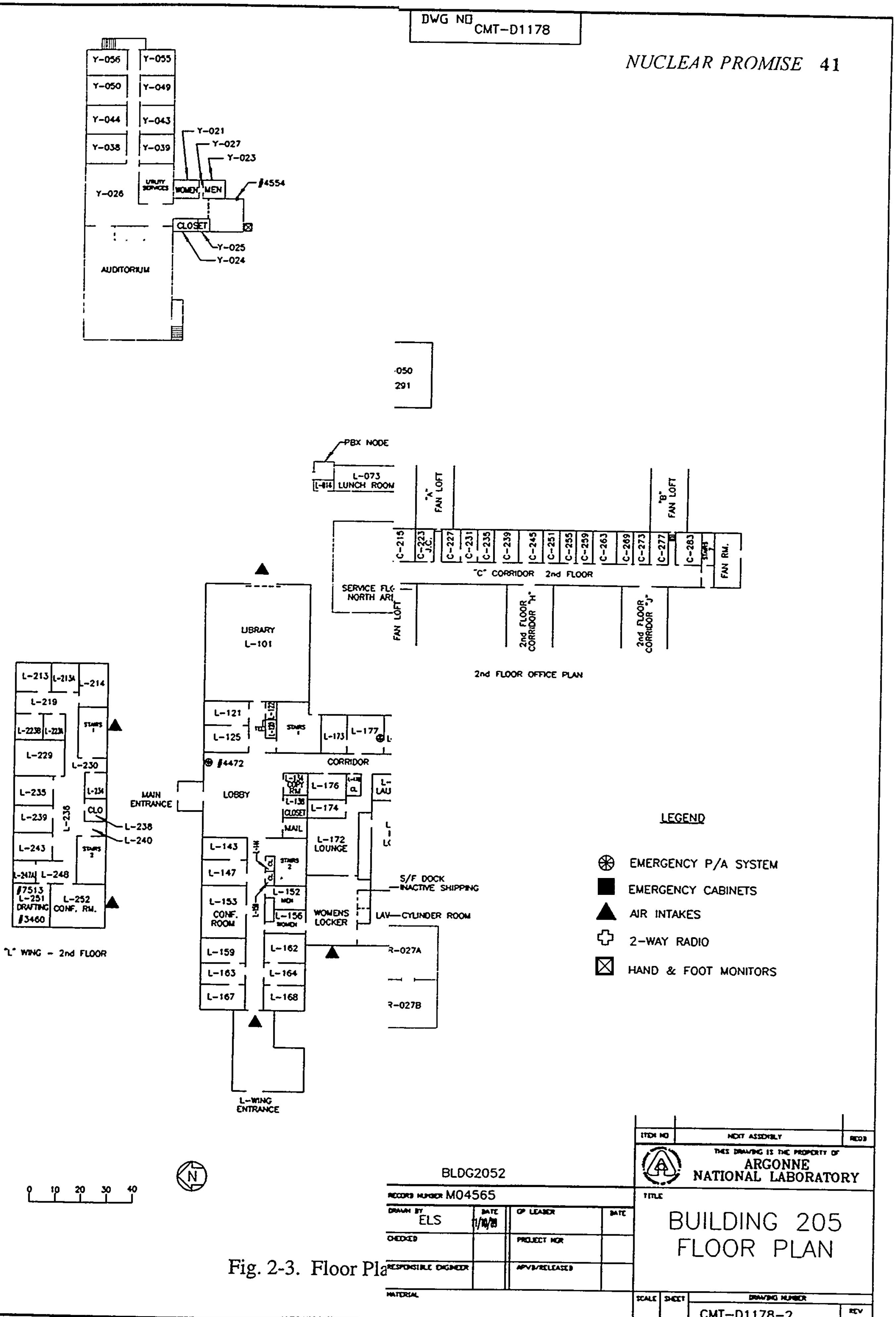


Fig. 2-3. Floor Pla

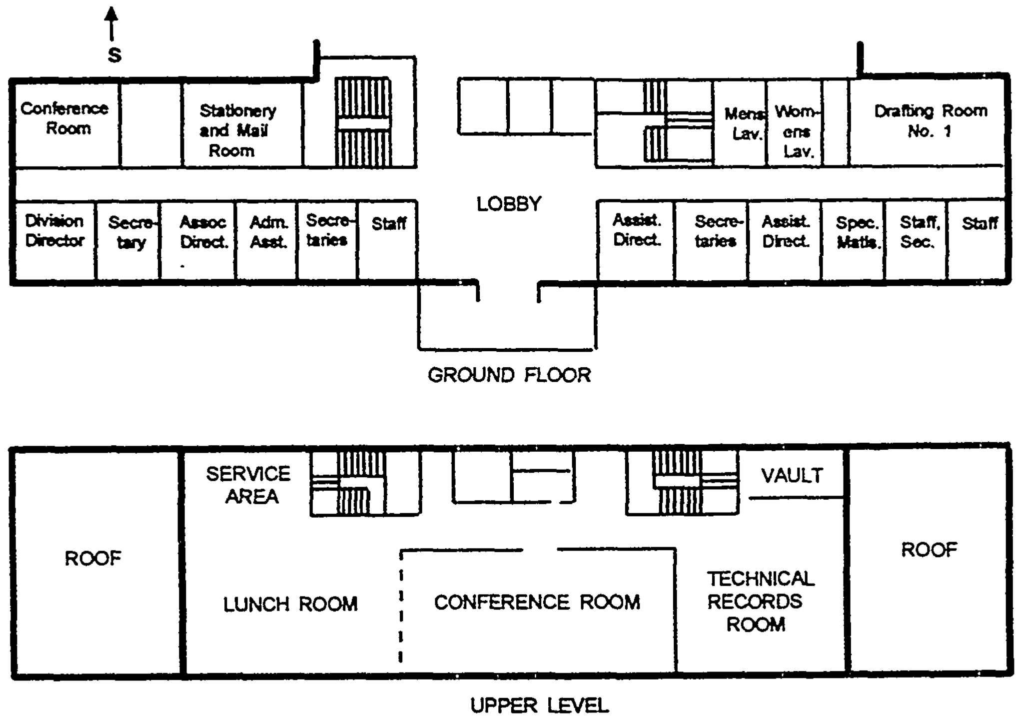


Fig. 2-4. Building 205 L-Wing in the 1950s

"Laney's Conference Room"; some old-timers still call it that. There was also a period when Robert Duffield claimed L-153 as a Laboratory Director's conference room, complete with carpeting and a teak wastepaper basket that attracted some comment. At present, L-Wing is occupied largely by CEN personnel and the library. The small offices where the mailroom and the copying machine are now located were originally intended to serve as two interview rooms and space for a future elevator, which was never installed.

The original building plan was based on the assumption that the Division would be involved in extensive work with radioactive materials, and the space now occupied by Jan Muller, Ron Tollner, and the secretaries was all allocated to health physics. The space where Ray Wolson's group is located was designated as a "control room."

C-Wing is now used largely according to the original plan, with the exception that the present radiation safety office once housed a first-aid facility and ventilation equipment. Some of the ground floor offices near A-wing were expected to serve as small machine and glass-blowing shops for the staff personnel, but they were never used for that purpose.

A- and B-Wings were planned as conventional chemistry laboratories and offices. Hauserman partitions® made of metal were used because of their modular construction, which made it relatively easy to rearrange the layout when the need arose. (The occupants soon discovered another handy feature—magnets could be used to attach various items to the walls.) When the building was occupied, there were normally three staff people per office. The office furniture was (and still is in many cases) standard government issue gray-colored metal desks, chairs, tables, bookcases, *etc.*, that are identical to those used on most Navy ships, except they are not welded to the floor. Most of the offices at ANL tend to be rather Spartan, with concrete block or metal walls, tile floors and concrete ceilings, but they serve their purpose well.

The A-Wing laboratories were used for research, primarily on solvent-extraction processes. Martin Steindler recalls much of the work going on in A-Wing at the time. Room A-101 was set up to accommodate Alberta Hoover's glassware washing for the Analytical Laboratory. Hal Feder, Norm Chellew, Ken Rhode, Don Hampson, and Milt Ader did much of the early pyrometallurgical research in A-109. Sy Vogler was dissolving enriched uranium from plastic planchets, and Bob Larsen with Roberta Shor was working on the problem of explosions when uranium-zirconium alloys are dissolved in nitric acid solutions. Chuck Seils and Bill Sovereign operated a plutonium analytical facility in A-133. (Bill later moved to the Idaho site.) Room A-141 was a plutonium lab where Martin Steindler, Fred Linzer, and Karl Schoeneman were doing fluorinations of fused salt materials and some thorium fluoride phase work. Max Adams and Dave Steidl came later into A-141 and worked in a Blickman hood in A-133 with bromine fluorides and uranium-plutonium alloys. Steindler also remembers a special project Feder had Don Fredrickson doing that used cyanide as a reagent, which generated an enormous flap with the medical people that went to upper management. Steindler still has the acetonitrile they gave him as an antidote for cyanide exposure.

B-Wing was devoted almost entirely to analytical chemistry. When the building was being designed, consideration was given to a third wing extending east from C-Wing the same as A- and B-Wings, but Dr. Lawroski agreed with Dr. Zinn that it could be eliminated in view of the budget limitations.

The high-bay areas, G-, H-, and J-Wings, were designed for engineering research with highly radioactive materials. Unlike most of the rest of the building, where there is a service floor beneath the working areas, these laboratories were built directly on undisturbed soil to support the weight of heavy shielding and equipment. Part of the rationale for the high ceilings (about 25 feet in G- and H-Wings, and 50 feet in J-Wing) was the expectation that much of the work would involve tall solvent-extraction columns. Heavy shielding in the form of high-density concrete was erected in several of the laboratories to accommodate such columns. Anybody who has had the task of drilling a hole through that concrete shielding to provide access to one of the cells has a special appreciation of its hardness and density. Traveling bridge cranes are used to handle heavy equipment in the high-bay areas. As it turned out, the process development work gradually shifted away from solvent extraction to other types of processes that required glove boxes and large walk-in hoods. Nevertheless, the shielded cells continued to be useful for a wide variety of research projects over the years.

The part of D-Wing that extends south from C-Wing contains the machine shop and a drafting room. The other part of D-Wing, situated at the southwest corner of the building, is occupied by various service facilities, including shipping and receiving docks, solvent storage, an electric transporter, and battery-charging station.

The building had Special Materials vaults in active use, with a criticality alarm that was tested periodically. The vaults are still there, but are no longer used to store special materials.

E-Wing, which is situated on the other side of the corridor, consists of the stockroom, a materials-storage area, and open space for shop operations such as welding and sheet metal work. In the early days of the Division, the stockroom was larger and had a much wider variety of supplies. Esmer Zeno, who was everybody's friend and liked to talk about his most recent "miseries," operated it. The early programs such as the development work on solvent extraction, pyrometallurgical processes for EBR-II fuel, and the fluoride volatility processes all involved the construction of large, complex equipment, often using rather exotic metals and other materials. The materials storage area in E-Wing was well supplied with hardware such as nuts and bolts, tubing connectors and fittings, Unistrut®, pipe and tubing, welding rods, and various sheet metals, as well as other commonly used supplies. As time passed, the need to reduce inventory costs and space resulted in a marked reduction of the supplies in the stockroom and materials-storage area.

F-Wing and parts of E-Wing include several laboratories that have been used mostly for special-purpose operations such as the microprobes and metallographs. R-Wing is made up of offices. These offices are generally occupied by staff people working in E- and F-Wings, and were used for many years by the CEN Editorial Group.

In 1956, the Senior Cave (Fig. 2-5) was added to the west side of Bldg. D-205 opposite G- and H-Wings, and it, along with its various service areas, was designated "K-Wing." The cave consists of three heavily shielded cells, each one equipped with viewing windows and master-slave manipulators. The original Mod 3 electronic manipulators, which were designed and built at ANL, attracted a lot of interest. They were often demonstrated for visitors and were always a favorite both with children and adults at the ANL open houses. One shortcoming of the original model was that the operator had no sense of touch when grasping an object. This was corrected by adding a feedback system so one could feel a resistance to the force being applied. Another interesting nicety that was added was small metal "fingernails" on the square tips of the rubber manipulator fingers to assist in picking up small objects. Later on, commercial manipulators became available and are now being used.

The requirement for safe handling of radioactive materials imposed many design considerations in the planning of the building.

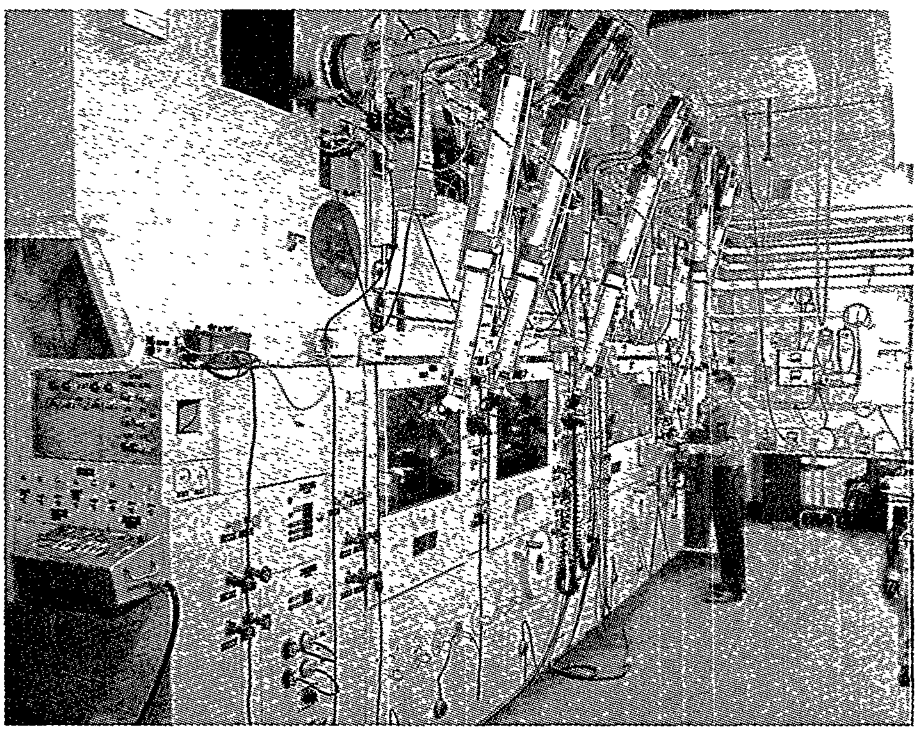


Fig. 2-5. Senior Cave in Building 205

One of the major ones was the ventilation system. Unlike commercial buildings where the air is recirculated, Building 205 uses a once-through system. Part of the outside air is drawn into the offices and other non-active areas, and exited through the laboratories from where it passes through the fan loft before it is exhausted to the outside. In the fan loft, the air passes through ultra-high-efficiency filters, which are sometimes called "absolute" or High Efficiency Particulate Air (HEPA) filters. These filters remove practically all the particulate material in the air, but not radioactive gases that might be released. With this arrangement, heating and cooling become complicated and expensive. For several years after the building was constructed, there was no air conditioning, and one could not open the windows, so it was often uncomfortably hot during the summers. On hot, humid days, condensed moisture on the overhead cool water lines in the laboratory areas dripped on the workers and their equipment. Some researchers used plastic tents to protect critical equipment. A few lucky people had equipment that required air conditioning, which was provided, and their labs tended to be visited frequently by the less fortunate on hot days.

Safety considerations dictated that the ventilation system must continue to function during power outages. To supply this need, as well as those of other critical systems in the building, emergency backup power was supplied by a 900-horsepower, 12-cylinder diesel engine on the service floor. As was usually the case, Milt Levenson had a story about that engine. He claimed that it was salvaged from a decommissioned LST (Landing Ship Tank) from WWII and dropped in San Francisco Bay in the process before it was completely overhauled and sent to Argonne. It was replaced later by a new unit.

Building 205 originally had three water systems: (1) domestic water, which was piped to all drinking fountains, washrooms, locker-room showers, eyewash fountains, and most safety showers, (2) the laboratory water system, which provided water to all the engineering areas and the laboratories for general-purpose use and cooling of equipment and apparatus, and (3) a system that consisted of two distilled water supplies, one for the high-bay engineering areas and the other for the A-, B-, and G-Wing laboratories. The distilled water system has now been supplanted by a relatively new deionization system for all areas. Three other new water systems have been installed in the building. A canal water system, in which water from the Chicago Sanitary Canal is filtered and supplied to ANL, is now used for cooling building operating equipment. A central cooling water recirculating system is used for the building air-conditioning equipment and for cooling some of the large laboratory-support equipment. The third is an in-house cooling water recirculation system that is piped to all engineering and laboratory areas to augment the existing laboratory water and to help reduce the water consumption in Building 205. The drainwater from the laboratories goes to retention tanks in a sub-basement, where it can be held and monitored for radioactivity or other contaminants before it is released into the Laboratory sewage system.

The laboratories are equipped with all the usual services such as hot and cold water, deionized water, natural gas, compressed air, vacuum, and nitrogen. Electrical power is available routinely at 120 and 208 V, and higher voltages can be provided where needed. One problem that developed with the Hauserman partitions in A- and B-Wings was that they came prewired with installed fuses for 208-V, single-phase power, to the chagrin of some who had to install industrial equipment that required 220-V, three-phase service. There was another problem with compatibility of connectors in the electrical boxes.

Building D-310

Building D-310 was completed and occupied before Bldg. D-205, but it was always an adjunct in that the Division headquarters was never located there. It is situated on the southeast corner of the intersection of Meridian and Rock Roads. As was the case for Bldg. D-205, Vorhees, Walker, Foley, and Smith of New York City were the architect-engineers. The construction plans refer to the structure as an "experimental waste processing, storage, and shipping facility." Figure 2-6 is a simplified version of the layout of Bldg. D-310, which was designed mainly to accommodate semi-works and radioactive waste-disposal studies. The building contained a machine shop area and five laboratories for supporting work. The laboratories were essentially the same as those in Bldg. D-205.

The extensive open area in this building, with a high ceiling and balconies, permitted work with large pieces of equipment. A three-ton bridge crane was provided at the loading platform to handle heavy shielding and equipment. The service floor, in addition to providing services for the main floor operations, included some of the operating equipment. For example, there is now a steel plate on the main floor that covers an opening where an incinerator extended from the service floor up into the main floor area.

Also underground was the "swimming pool" where highly radioactive fuel assemblies were located under water to provide shielding and still permit visual observations. This facility, designed under the direction of Phil Fineman, was used for high-level gamma irradiation experiments with food and other materials. This facility was located underground just south of the main building. Various types of gamma irradiations, including food-preservation studies that were conducted in this facility are described elsewhere.

Although Bldg. 310 was used intensively by CEN for several years, the Division's work shifted gradually to other projects that could be handled more efficiently in Bldg. 205. The waste-disposal work continued for many years, however, primarily as a facility for incinerating combustible dry active wastes and treating radioactive liquid wastes produced at ANL. The building was also used extensively to develop and test equipment for use in the EBR-II Fuel Cycle Facility (FCF), which was being built adjacent to the reactor at ANL-W. The Chemical Engineering Division played a large role in this development; it was one of

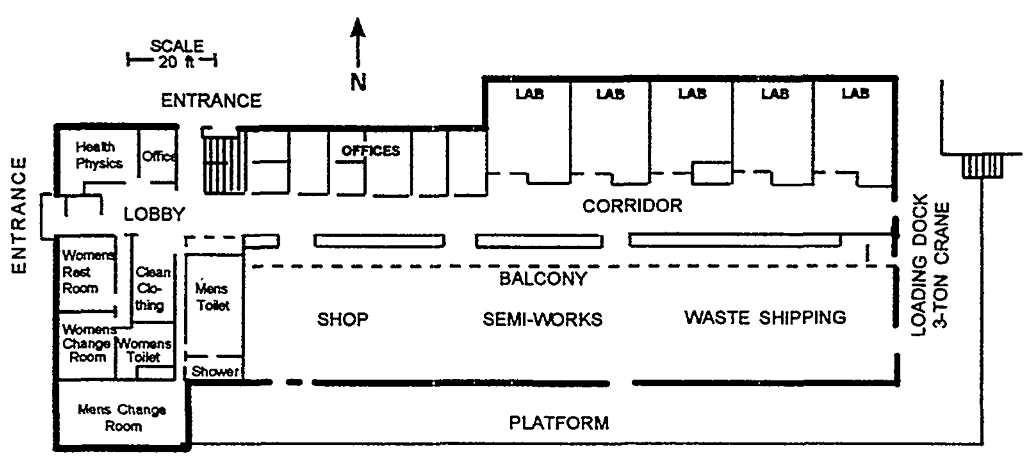


Fig. 2-6. Floor Plan of Building 310