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EDWARD CHESTER CREUTZ
1913–2009

A Biographical Memoir by

GEORGE HINMAN AND DAVID ROSE

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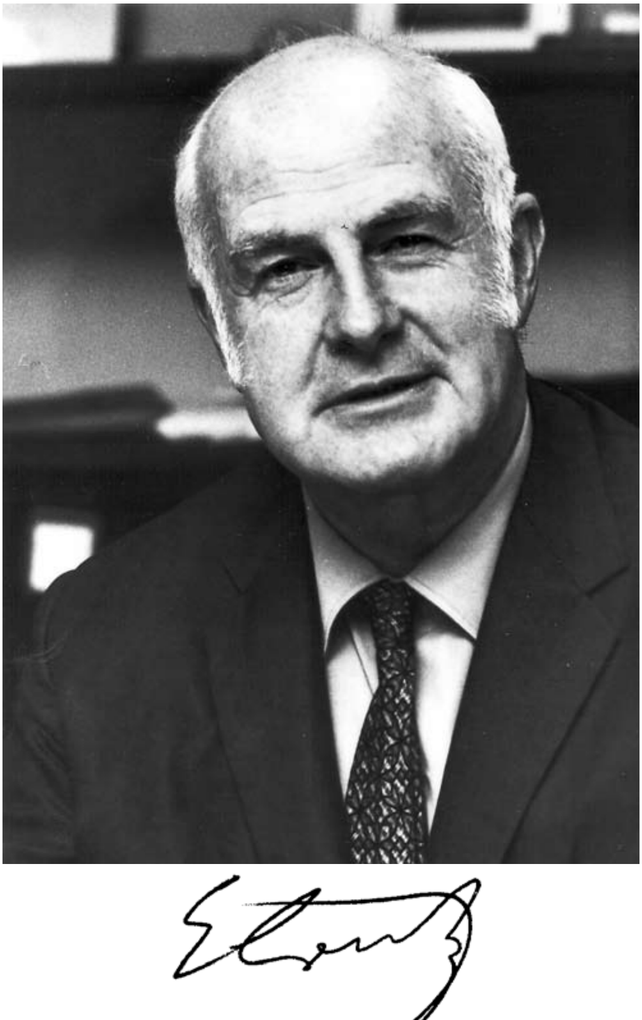

EDWARD CHESTER CREUTZ

January 23, 1913–June 27, 2009

BY GEORGE HINMAN AND DAVID ROSE

EDWARD CREUTZ BEGAN HIS PROFESSIONAL CAREER at a historic time. He arrived at Princeton University in 1939 when World War II was beginning and physicists were just learning about nuclear fission. Both events greatly affected his early years. As the national security implications of nuclear fission became clear, his initial research at Princeton shifted from nuclear interactions and radioactive decay to the properties of chain-reacting piles and nuclear explosives. His experimental work at Princeton and later at the University of Chicago and Los Alamos was fundamental to the development of plutonium production reactors and plutonium-based explosives. For a brief period from 1942 to 1945 he joined much of the nation's nuclear physics community in the Manhattan Project, the remarkable effort that led to the end of World War II. After the war, he left Los Alamos and continued a career that included prominent positions in academia, the nuclear industry, the federal government, and a private museum. Throughout his career he continued to lecture and publish on a wide range of topics in physics, metallurgy, biology, science education, and science policy.

Ed was born in Beaver Dam, Wisconsin, on January 23, 1913, during a snowstorm, he says in his anticipatory obituary.[1] His father, Lester Creutz, was a high school history teacher and later a school administrator, and his mother, Grace Smith Creutz, taught general science before the birth of his older brothers, John and Jim. The family moved from Beaver Dam to Eau Claire, then to Monroe, and finally to Janesville, Wisconsin, as his father advanced in the public school system. Ed's sister, Edith, was born in Eau Claire. They were very close as children and remained so in later life.

As would be expected, Ed liked mathematics and science subjects in school, but he also pursued many interests outside the classroom during his elementary and high school years. In high school he taught himself to play the banjo, left handed, and later added the mandolin, ukulele, percussion instruments, and trombone. He played base drum in the high school band, tympani and banjo in the orchestra, and tenor banjo in Rosie's Ragadors, whose members performed at local dances and other events. He went out for football and played left guard on the high school teams in Monroe and Janesville. He was proud of the fact that in Monroe he played every minute of every game. Ed was especially interested in biology in his early years. He collected insects and reptiles and read widely in the field. He developed a strong interest in color photography, experimented with nearly all the processes known at the time, and developed his own process using black and white printing paper but adding color with heavy metal salts. He continued work on this subject in later years.

When he graduated from high school, Ed did not proceed to college right away. He took a job as bookkeeper in a local bank in Janesville in order to help with the family finances—his two brothers were in college at the time. In the fall of 1932 his brother John convinced him to go to college, and he entered the University of Wisconsin at Madison. He considered majors in botany, geology, and chemistry but decided on physics when John told him that it was basic for the other sciences. He progressed through the physics curriculum and became acquainted with his instructors, several of whom became lifelong friends and colleagues. His freshman course professor was Julian Mack, who introduced him to research by giving him a small research project to do during his freshman year. One of us (G.W.H.) remembers when, 20 years later, Ed invited Mack to General Atomic at San Diego as a consultant. Ed gave him a small tool kit and invited him to get to work just as Julian had done for him so many years before. Other influential faculty at Madison were Ragnar ("Rollie") Rollefson, his junior physics instructor; Raymond Herb, who helped him develop important research skills; Gregory Breit, his Ph.D. dissertation sponsor; and especially Eugene Wigner, who inspired and guided much of his early work. It was during this period that he developed many of the skills that served him well as an experimental physicist. As a senior thesis he built and used equipment to separate the two isotopes of lithium, although no thesis was required for graduation. He received B.S. degrees in mathematics and in physics in 1936.

Ed remained at Wisconsin for graduate work He was increasingly drawn to the new field of nuclear physics and worked on Ray Herb's project to upgrade the proton energy of the department's Van de Graaff generator from 300 KeV to 600 KeV. The improvement provided enough energy for him to undertake as his dissertation a suggestion by Gregory Breit to study resonance scattering of protons from lithium at a narrow 440 KeV resonance, where previous investigations had shown that proton bombardment produced high-energy gamma rays. The mechanism responsible for the gamma rays was unknown and was of considerable interest at the time. Ed's measurements showed that the gamma rays arose from direct decay of a virtual level of the compound nucleus ^{8}Be and not from an excited alpha particle produced after double alpha particle decay of the level (1939). It also was during this graduate student period that he met Lela Rollefson, Rollie's sister, who was a mathematics student at the time. They married on September 13, 1937. Lela was interested in science, and for a number of years at Wisconsin and Princeton she helped Ed with data collection and analysis. He includes acknowledgements of her assistance in publications from that period.

By the time Ed was in graduate school he had established himself as a valuable and skillful experimenter who was able to get things done. Eugene Wigner moved from Wisconsin to Princeton in 1938, and Ed soon received an offer of a position there. The University of California had given Princeton a 36 inch magnet, which the Physics Department used to construct an 8 MeV proton cyclotron. The department hired Ed to help get the cyclotron into operation. He moved to Princeton and joined the research group working with the new machine. Ed loved to tell the following anecdote about one of his early experiences at Princeton:

> On my third day at Princeton, I was invited to give a short report on my thesis. There usually were two or three speakers at these "Journal Club"' meetings. This time the speakers were Niels Bohr, Albert Einstein, and Ed Creutz! To be on the same program with these two giants of scientific accomplishment was breathtaking. Just before the meeting began, my sponsor, Delsasso, asked me, "Say Creutz, have you met Einstein yet?" I had not. Delsasso took me over to where Einstein was sitting in sweatshirt and tennis shoes and said, "Professor Einstein, this is Creutz, who has come to work on our cyclotron." The great man held out his hand, which seemed as big as a dinner plate, and said in an accented voice, "I'm glad to meet you, Dr. Creutz." I managed to wheeze out, "I'm glad to meet you too, Dr. Einstein."

Life went on, but not in the same way. Bohr had brought to the meeting the details of the discovery of the fission of uranium, an entirely unexpected development in physics.

In the period from 1939 to 1941 Ed worked with other members of the Physics Department at Princeton on projects that led to 19 journal papers on experimental techniques and nuclear experiments. The most extensive set of experiments, carried out with M. G. White, L. A. Delsasso, and others, dealt with light "Wigner" nuclei, each of which contains a number of neutrons exceeding by one the number of protons. When such a nucleus is bombarded with energetic protons, it can through a (p,n) reaction be converted to a nucleus whose proton number exceeds by one the neutron number. Wigner had pointed out that if the neutron-neutron nuclear force and the proton-proton nuclear force are equal, the energy difference between the original and product nucleus should be approximately equal to the difference in the Coulomb energy of the two. This difference could be determined by measuring the endpoint energy of the positrons emitted by the product nucleus. The results of the Princeton group's work on eight of these nuclei, combined with similar work elsewhere on four others, showed good agreement with expectations (1941).

By 1941 the discovery of nuclear fission, and especially its neutron multiplication property, was claiming the attention of nuclear physicists. While there was general interest in the physics of the process, many physicists already realized its weapons potential. Leo Szilard, Edward Teller, and Eugene Wigner had already, two years before, composed a letter to President Roosevelt, actually signed by Albert Einstein, pointing out that Germany might develop a powerful new bomb based on the process and urging that work on this subject should be undertaken in the United States. The two substances that could form the basis for a nuclear bomb were the uranium isotope ^{235}U, which constitutes a very small fraction (0.72 percent) of naturally occurring uranium, and the plutonium isotope ^{239}Pu, which is a decay product of neutron absorption in ^{238}U, the major fraction (99.28 percent) of natural uranium. For various purposes, including, as it turned out, production of ^{239}Pu, the nuclear physics community began to study the characteristics of a fission chain-reacting assembly as a prolific source of neutrons.

Enrico Fermi and Leo Szilard at Columbia decided to explore an assembly based on thermal neutrons as the fission-inducing agents. Princeton followed the same path. Because the neutrons released in the fission process have high energy, it is necessary to include a low atomic weight material in the assembly to slow the neutrons down to thermal energy by elastic collisions. Wigner and his associates at Princeton, like Fermi, focused on natural uranium in a graphite matrix as an assembly of this type. Under Wigner's guidance Ed assembled 2 tons of very pure graphite blocks and used (p,n) reactions at the Princeton cyclotron to produce a neutron flux inside the assembly. With this system the Princeton group measured the absorption of neutrons in uranium oxide specimens (uranium metal was not available at the time) as the neutrons slowed down through an energy region of sharp uranium absorption resonances on their way to thermal energy. A series of such experiments on uranium oxide "lumps" of various sizes and shapes, and over a range of temperatures, demonstrated that by lumping the uranium oxide rather than distributing it uniformly through the graphite, the neutron absorption in the uranium could be reduced and the efficiency of a chain reaction process substantially improved. When these experiments were carried out, they were highly classified because of their national security implications. When they were finally declassified and published in a series of four papers in the *Journal of Applied Physics* (1955), the editors of the journal introduced the series saying they had already become classics in the science of reactor technology (1955, p. 257). The experiments were critically important in the evolution of the design for the plutonium production reactors at Hanford, Washington. They led to the choice of water cooling and a simple structure for the reactor core.[2] Wigner and his research group developed the conceptual design for this system, whose essential features are described in a patent issued to Creutz, Ohlinger, Weinberg, Wigner, and Young (1959). The original choice for coolant in the Hanford reactors was helium gas because helium does not absorb neutrons. However, helium cooling would have required equipment that could not be obtained for many months because of wartime pressure on manufacturers.[3] Wigner's design prevailed.

In 1942 Ed moved to the Metallurgical Laboratory at the University of Chicago. The Metallurgical Laboratory was the code name for the part of the Manhattan Project assigned to develop the technology for a plutonium production reactor. Many of the country's distinguished nuclear scientists and engineers, including Enrico Fermi, Hans Bethe, Eugene Wigner, and others, gathered there. Ed was a member of the Engineering Council, established by Arthur Compton, to guide the effort, and he led the first group to undertake metallurgical studies on the properties and fabrication methods for uranium, beryllium, and aluminum. His patents and publications from this period show that he personally worked on extruding rods and tubes of uranium and beryllium metals, forging beryllium, jacketing fuel elements, soldering several relevant metals, and measuring corrosion of metals in close contact with rapidly moving liquids. The group also worked on critical mechanical and heat transfer problems for the reactor.[1,3] Over the course of two years Ed and his associates, in conjunction with DuPont's engineers, developed successful fuel element designs and fabrication methods (1959) for the future reactors at Oak Ridge and Hanford.[4] In a review of this work Frederick Seitz and Alvin Weinberg estimated that Ed's intensive activities, and those of his section at the

Metallurgical Laboratory, shortened the time for production of plutonium by at least two years (private communication from Fred Seitz to D. Rose, Aug. 5, 2003).

In late 1944 when the success of the production reactors seemed assured, Ed and Lela moved to Los Alamos, New Mexico. Los Alamos was the Manhattan District site where the development, testing, and production phases of the uranium and plutonium bombs were carried out. Ed marks the first major event there as the birth of his son, Michael. Ed joined E. M. McMillan's group in the development of the implosion technology for the plutonium bomb. The critical problem at the time was holding the plutonium together in a compact shape long enough to initiate a large explosion rather than an ineffective disintegration. Firing one part of the fissionable material into another, which worked for the uranium bomb, did not work for the plutonium bomb. It wasn't fast enough. The alternate trigger mechanism involved surrounding the plutonium on all sides by a spherical shell of high-explosive lenses and firing them simultaneously toward the center to squeeze the plutonium and hold it together long enough to achieve an adequate yield. This was the implosion trigger. Ed served as group leader responsible for lens design confirmation and preliminary testing of this concept at Los Alamos before the actual bomb test at the Trinity site in southern New Mexico. Two days before the Trinity shot a full-scale dummy test was fired with a non-fissionable core in Pajarito Canyon near Los Alamos. One of us (D.R.) was responsible for that test. The diagnostic results seemed to predict a failure at Trinity, causing great consternation at the site. However, Hans Bethe, working all night, demonstrated that the distortion of electromagnetic radiation from the explosion would produce the observed results if the test, in fact, had been successful.[5] The Trinity test went forward, and it worked. The date was July 16, 1945. Of the two atomic bombs subsequently exploded over Japanese cities, the first on August 6 at Hiroshima was a uranium bomb and the second on August 9 at Nagasaki was a plutonium bomb. The Japanese emperor effectively ended the war on August 14.

In 1946 Frederick Seitz, who was head of the Physics Department at Carnegie Institute of Technology in Pittsburgh, invited Ed to join the department as associate professor and to lead a new nuclear physics faculty group. Ed accepted and brought with him Roger Sutton and Jack Fox, who had participated with him in earlier research at Princeton. Nuclear physics research was headed toward higher energy, requiring a new type of particle accelerator. The conventional cyclotron design had reached an energy limit because it could not accommodate the relativistic increase in particle mass at high energy. With Seitz's help Ed received financial support from the Office of Naval Research to design and construct a 450 MeV proton synchrocyclotron, a new design at the time. It modified the acceleration process to overcome the energy limitation, although it produced an intermittent rather than a constant particle beam. Carnegie Tech had competition for this project from the University of Chicago and Columbia University, both of which were also building synchrocyclotrons. Ed determined to produce the best of the new machines. He undertook an experimental and analytical study to minimize the combined capital and 10-year operating cost of the magnet, the principal cost component. The effort succeeded. The Carnegie Tech magnet, at 1500 tons, weighed several hundred tons less than its nearest competitor.[6] Much of the credit for the design belongs to Martyn Foss, who had been with Ed in Chicago and Los Alamos and who used the design work for his D.Sc. dissertation. Ed established a new facility, the Nuclear Research Center, at Saxonburg, Pennsylvania, and constructed the new accelerator at this site.

In 1948 Ed became head of the Physics Department, in addition to director of the Nuclear Research Center, when Seitz moved to the University of Illinois. The stature of the department in the physics community continued to grow under Creutz's leadership as he brought new faculty and visiting scientists to Pittsburgh. Lincoln Wolfenstein, Herbert Corben, and Sergio DeBenedetti were early arrivals. Walter Kohn and Julius Ashkin joined the department in 1950 and Gian-Carlo Wick in 1951. Richard Becker and Siegfried Flugge came for academic-year visits. Gilberto Bernardini, during a visit, found and identified the first sure track in a photographic emulsion of a meson produced by the new machine. Research with the synchrocyclotron at the Nuclear Research Center turned to the production of meson beams and their interactions with nuclei. Work continued until the next generation of accelerators at higher energies and currents became available and made the Saxonburg accelerator obsolete. However, the legacy of that work remained in the form of vigorous, medium- and high-energy nuclear and particle physics programs carried on by Carnegie Mellon groups at various national and international accelerator laboratories.

Ed's second son, Carl, and daughter, Ann Jo, were born during his tenure at Carnegie, and Ed brought the same enthusiasm and energy to his family life and to other wide-ranging interests that he applied to physics and related technologies. He had an early and lasting interest in flowers and grew orchids in his home. He published various findings on different floral species in botanical journals, a total of eight from 1954 to 1967. Among his publications are descriptions of three new varieties of violets, which he named for his three children, Michaeli, Carli, and Annjoae. One of his papers, which appeared in the New York Botanical Garden Journal (1966), was on the tiare apetahi, a rare flower found only on a mountain plateau on the island of Raiatea, reached after a two-hour hike. Ed and Ann Jo made it at least twice. It confirms his love of the outdoors. For many years he and his family (those old enough to go—at least three years old for Ann Jo) took extended canoe trips in Quetico Provincial Park near Lake Superior in Canada and later camping trips in California at Kearsarge Pass near Mt. Whitney and in the Anza-Borrego Desert. Another long-standing interest was Polynesia and Polynesian dialects, especially Tahitian. He was a serious student of Hawaiian and Tahitian. When he did not find a satisfactory Tahitian grammar in English, he translated one from the French and published it.[7] Over the course of his career he traveled to at least a dozen Polynesian islands, and he and Lela temporarily "adopted" two young Polynesians, who lived for a time with the Creutz family before returning home.

By 1955 Ed had become interested in the possibility of thermonuclear fusion as an energy source, and he spent a year during 1955-1956 as scientist-at-large at Los Alamos evaluating the United States' controlled thermonuclear program for the U. S. Atomic Energy Commission. During the year, Frederic de Hoffmann invited him to join in establishing the General Atomic Division of General Dynamics Corporation, dedicated to scientific research and development of nuclear energy. He became vice president for research and development and director of the Research and Development Laboratory at the General Atomic site in La Jolla, California. During early years at General Atomic, the company selected two principal products for development. One was a small reactor for training, research, and isotope production, appropriately named TRIGA.[8] It incorporated unique uranium-zirconium hydride fuel elements that accomplished much of the neutron moderation within the fuel elements themselves, producing a fast shutdown mechanism that made the TRIGA a very safe reactor even for pulsing operation. It became a basic tool for use at universities, government and industrial laboratories, and medical centers. More than 60 were eventually installed in many countries around the world.

The second product was a large power reactor, the HTGR, which was graphite moderated and helium cooled. General Atomic devoted its principal efforts to the commercialization of this reactor, which could produce higher-quality steam and had other significant advantages over the current light water power reactors. Two of these units were built for commercial operation. The first was a small demonstration 40 Mw unit at Peach Bottom Township, Pennsylvania, for which one of us (D.R.) played a major role. It performed well, but the second, a 330 Mw unit at Fort St. Vrain, Colorado, experienced problems and was eventually terminated. The HTGR concept was not further adopted at the time but has remained under consideration for process heat or electricity production.[9]

Laboratory groups at General Atomic undertook other research projects at the time, some to produce new products and others to fulfill contract research objectives for various sponsors. Among the most enduring and successful research was the work on magnetic confinement and heating of plasmas as a part of the national fusion-energy research program, the area that Ed brought with him from Los Alamos.

Ed had administrative responsibility for research and development projects at General Atomic, later Gulf General Atomic, and played a major role in determining the overall course of the company. In addition, he carried out active research of his own. While he was at General Atomic he worked on topics related to major interests of the company. One was the diffusion of gases through porous media (1964), likely related to the HTGR, which exposed the graphite moderator and other containment vessel internals to the helium coolant. The other was high-speed flow of hydrogen, helium, and argon mixtures through helical capillaries (1970) as a way of separating molecular species. Although he did not say so in his publications, it seems likely that he had in mind separation of deuterium from ordinary hydrogen as a source of fusion fuel. He had achieved a small degree of separation of argon from helium by this method before he left Gulf General Atomic. During the period 1962 to 1974, he published six papers on these subjects and secured one patent, assigned to Gulf General Atomic (1969).

In later years Ed took an active interest in a number of general science subjects—public understanding of science, science education, interdisciplinary research, funding allocations for scientific research, and relationship of research to energy technologies. He published papers and delivered lectures on these subjects and participated in a number of scientific and educational committees. He was for six years a member of the Divisional Committee for Science Education of the National Science Foundation and served as a director-at-large of the Governing Board of the American Institute of Physics. He was a fellow of the American Physical Society, the American Association for the Advancement of Science, and the American Nuclear Society, and a member of the academies of science in California, New York, and Pennsylvania. While in San Diego he was a fellow and director of the San Diego Natural History Society and a director and vice president of the San Diego Hall of Science and Planetarium. In 1962 he received the Greater San Diego Industry-Education Award for promoting scientific education.[10]

In 1970 the President appointed Ed to serve as assistant director for research at the National Science Foundation. In this position he initially managed a group of NSF staff members whose principal function was to do long-range planning of basic scientific research and to carry out a grants program supporting the results. In 1975 following reorganization at NSF, he became assistant director for mathematical and physical sciences, and engineering, and he assumed responsibility for those areas. In 1976-1977 he served as acting deputy director.

Beginning in 1973, he was active in responding to the President's urgent request for a review of federal and private energy research and for an integrated energy research and development program for the nation. This was the period of the Arab oil embargo, from October 1973 to March 1974, which focused the country's attention on the consequences of its dependence on oil imports. Ed served as a panel chairman for a major study, published as "The Nation's Energy Future".[11] It led to substantial increases in the nation's energy research, and Ed was responsible for planning a program to invest NSF funds in areas of basic research needed for energy development. In recognition of his significant contributions he was awarded the National Science Foundation's Distinguished Service Award. In 1975 he was elected to the National Academy of Sciences.

Ed suffered a deep personal loss in 1972 when his wife, Lela, died of cancer. He later wrote that the period after her death was a turbulent time for him, and he was thankful that his children were old enough to be establishing themselves by then. Michael and Carl both became productive scientists, Michael at Brookhaven National Laboratory and Carl at the University of Virginia. Ann Jo completed degrees in biology and special education and became a special-education teacher. He said that he had the good fortune two and a half years later to marry Elisabeth ("Bettie") Cordle, who was working for the National Science Board at the time. They already shared many interests and together developed new ones. Bettie became an orchid enthusiast herself and extended Ed's orchid-growing activities to include wide-ranging searches for plants in the wild, which Ed photographed. The family Christmas cards began featuring pictures of orchids in place of the earlier fractals. Bettie also became a camper on the canoe trips and the visits to the desert, and she accompanied him on his later visits to Polynesia.

In 1977 Ed extended his long-standing interest in Polynesia by taking a position as director of the Bernice Pauahi Bishop Museum in Honolulu. Bernice Bishop, who died in 1884, was the last remaining member of the royal Kamehameha dynasty in Hawaii. In 1889 her husband, C. R. Bishop, a wealthy businessman and banker in Hawaii, established the museum to house her collection of Hawaiian artifacts and family heirlooms. In 1896 he helped redesignate it a "scientific institution for collecting, preserving, storing and exhibiting specimens of Polynesian and kindred antiquities, ethnology, and natural history…and the publication …of the results of such investigation and study."[12]

The museum has had a long and distinguished reputation for its collections and research in the Pacific area, and Ed extended the scientific program through improvements in staff and funding. He was especially pleased that during his tenure the staff, led by Seymour Sohmer, undertook preparation of the two-volume *Manual of the Flowering Plants of Hawaii.*[13] He also introduced a number of new educational and public outreach programs that increased public participation in and awareness of the museum. He had to spend much of his time working to cut costs and increase income, as financing the museum was an increasing challenge. He succeeded in approximately doubling the budget and secured funding for two major new buildings, but financing remained precarious.

Ed retired in 1984. He and Bettie returned to California in 1987, where he said that he enjoyed the climate and camping in the desert but liked to vacation in the Midwest where there were more wild orchids. He was recognized on several occasions for his contributions to nuclear science. In November 1992 at the International Symposium Commemorating the 50th Anniversary of CP-1, the first man-made, controlled nuclear chain reaction in Chicago, he was one of a number of "distinguished pioneers of the nuclear era who were honored for having been singularly instrumental in laying the foundation for, and in continuing contributions to, the worldwide utilization of nuclear power, nuclear medicine, and other beneficial uses for mankind arising from nuclear applications."[14] Included in the distinguished list of honorees, among others, were Eugene Wigner, John Wheeler, Alvin Weinberg, Edward Teller, Walter Zinn, Glenn Seaborg, and Enrico Fermi (posthumously). In March 2003 at the age of 90 Ed gave the banquet speech at the Fifth Symposium on Current Trends in International Fusion Research in Washington, D.C. On June 27, 2009, at the age of 96 he died of natural causes at his home in Rancho Santa Fe.

Edward Creutz was indeed a distinguished pioneer of the nuclear era. He was a skillful, thoughtful, and innovative experimenter on his own as well as a successful organizer and leader of others. At Princeton, Chicago, and Los Alamos he made major contributions to the scientific and technological effort that advanced nuclear fission from an unexpected scientific discovery in late 1938 to a practical source of vast energy with applications to both war and peace by 1945. He continued to contribute to nuclear science and energy through his career and was highly regarded for his efforts. Those who knew him also recognized that he had a wide range of other interests, which he pursued with equal energy and originality.

WE WANT TO THANK Elisabeth Creutz, Michael and Carl Creutz, and Ann Jo Cosgrove for supplying unpublished materials and personal accounts that were essential for the preparation of this memoir. We also wish to acknowledge valuable conversations with Richard Atkinson, Paul Craig, and Howard Kratz.

NOTES

1. E. Creutz. Obituary. Anticipatory. Unpublished manuscript dated Jan. 23, 1996. Much of the personal information in this biographical memoir appears in two unpublished family documents: this anticipatory obituary and an oral history recorded by Carl Creutz in 1976.

2. R. Rhoads. *The Making of the Atomic Bomb,* p. 498. New York: Simon and Schuster, 1986.

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4. See also the competition between the Metallurgical Laboratory and DuPont for the Hanford reactor design in R. Hewlett and O. Anderson, *The New World,* chap. 6. The Pennsylvania State University Press, 1962.

5. R. Rhoads, *op. cit.,* p. 663.

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