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KENNETH TOMPKINS BAINBRIDGE

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A Biographical Memoir by

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Kenneth T. Bainbridge

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KENNETH TOMPKINS BAINBRIDGE was recognized early in his scientific career for his design and applications of mass spectrographs as research tools for nuclear mass measurements. His precise measurements of mass differences between nuclear isotopes, when compared to the energies of decay radiations, allowed him to confirm the mass-energy equivalency of A. Einstein. In collaboration with the late J. Curry Street[1] he designed and built the cyclotron at Harvard University that was sent to Los Alamos, New Mexico, during World War II. Bainbridge participated in the formation of the wartime Radiation Laboratory at MIT, where he spent more than two and one-half years developing microwave radar, particularly high-powered systems. In the spring of 1943 he transferred to the nuclear weapons project at Los Alamos, where he oversaw the test explosion of the first nuclear bomb at Alamogordo. Returning to Harvard after the war, he renewed his work with mass spectrographs, began the construction of a new cyclotron, and was able to measure changes in the decay rates of some radioactive nuclei resulting from differing molecular bonding and from physical compression.

FAMILY BACKGROUND

Kenneth Bainbridge was born on July 27, 1904, in Cooperstown, New York, the second of three brothers. He grew up in New York City, attending the Horace Mann School and the Horace Mann High School. He attributed his early interest in technology to the influence of two uncles who were engineers. His Uncle George worked on switching and safety devices for the New York subway and conceived a form of safety braking, but he was beaten out by Westinghouse, which had developed a better system. The Bainbridge family lived on Riverside Drive near 158th Street and the Hudson River, where just after World War I returning naval vessels docked. As a high schooler, Ken became interested in radio; on the family's rooftop he put an antenna that came to the attention of ship radio operators, who would knock on his door to investigate. These contacts enabled him to acquire rare 5-watt vacuum tubes from his callers for a couple of dollars. With those tubes he was able to set up a radiotelephone, obtained a radio amateur license, and operated a "ham" station with call letters 2WN (this was before the national prefix letter "W" was used.)

COLLEGE YEARS

Ken gave up his activities in radio and schoolboy chemistry, when in 1921 he entered MIT to study electrical engineering in a cooperative program with the General Electric Company. In that five-year program he was able to receive both an S.B. and an S.M. degree and to work summers at one of the General Electric facilities. In Ken's case this was at first in Lynn, Massachusetts, and then mostly at the Research Laboratories in Schenectady, New York. After completion, a natural consequence of his participation in the cooperative program with GE would have been for him to continue as an engineer at General Electric. As an outgrowth of his work there, Ken obtained patents on photocathode materials for photocells[2] and on amplification of photocurrents by secondary emission cathodes[3]. His work at the GE laboratories had, however, brought him to realize that his strong interest was in physics, and his colleagues there advised him to look to Princeton University for graduate work. Among those advisors was Karl T. Compton, who served as a consultant to GE and was then head of the physics department at Princeton.

With Tom Killian, his friend from his years at MIT, Ken applied to Princeton, and they were admitted in 1926. He described the two young men's interview with Dean West soon after their arrival, and credited West with saying, "You're nice boys, but it's too bad you never went to college." After repeating that story, Ken usually indicated that, with his immersion into the collegiate Princeton atmosphere, he had soon somewhat made up for that lack in his background. As a graduate student in physics at Princeton, he became interested primarily in the developing study of nuclei, which had not yet become well covered in formal course work.

Ken's initial attraction to mass spectroscopy was excited by his desire to search for the then undetected element 87 of the periodic table, an element that should behave chemically as a heavy alkali, and which he therefore would call eka-cesium. He searched for it mainly in materials extracted from ores that were rich in the lighter alkalis—lithium, sodium, potassium, rubidium, and cesium—without success. Element-87 turns out to exist naturally only as short-lived isotopes resulting from the decay of actinium, the longest-lived having a half-life of 22 minutes. It was finally found in 1939 by Marguerite Perey at the Curie Laboratory of the Radium Institute of Paris, and hence has become known as "francium."

THE YEARS BEFORE WORLD WAR II

After completing his Ph.D. program at Princeton, Ken Bainbridge spent four years, first as a National Research Council fellow and then as a Bartol Research Foundation fellow, at the Franklin Institute's Bartol Research Foundation. The "Bartol" was then located on the campus of Swarthmore College in Pennsylvania, and was directed by the eccentric Englishman, W. F. G. Swann, who was especially interested in research on cosmic rays and nuclear physics. (I use the term "eccentric" in recalling his frequent participation in the meetings of the American Physical Society with comments from the front row seats. He often carried his cello along and his long white hair, perhaps even then less remarkable for a musician, was quite unconventional at that time for a physicist.) It was there that Ken continued to develop his mass spectrographs and to undertake precise nuclear mass measurements, which he used to confirm the mass-energy equivalence, $E = Mc^2$.

In September 1931 Ken and Margaret ("Peg") Pitkin, then a member of the Swarthmore teaching faculty, were married. In the summer of 1933 they traveled to Cambridge, England, where, as a John Simon Guggenheim fellow, Ken joined Lord Ernest Rutherford's Cavendish Laboratory, then a world leader in experimental nuclear physics. Ken described (1975) his first encounter there with the idea of a nuclear chain reaction when Rutherford stopped him in passing in a corridor to ridicule as obviously impractical a suggestion just made to him by a visitor, Leo Szilard, for such a process based on protons. Szilard went on to envisage a much more practical process involving neutrons, which, of course, only became reality after neutron-induced uranium fission was discovered. At Cambridge Ken continued to pursue mass spectroscopy and began a continuing close friendship with John D. Cockroft (later to become Sir John). Martin K. Bainbridge, the first child of Ken and Peg was born in Cambridge, England, in 1933.

In September of 1934 Ken returned to the United States and began his long association with the physics department at Harvard University. He built and employed the improved mass spectrograph he had designed during his sojourn at the Cavendish Laboratory. With the collaboration of J. Curry Street he also undertook to build a cyclotron. He was grateful to E. O. Lawrence of the University of California at Berkeley for assisting them in the design by sending details of his new 37-inch cyclotron. It was a lifelong characteristic of Ken's style that he thoroughly documented all of his projects and, to emphasize that point, he said (1975), "In the event the cyclotron was ever mislaid, stolen, or borrowed, I knew I could identify it—and later did at Los Alamos." The operational cyclotron was requisitioned in 1943 by the U. S. Army, dismantled, and rebuilt at the weapons laboratory. It remained there after the war, never to return to Harvard.

Bainbridge's interest in mass spectroscopy of nuclei led him to modify the naturally occurring abundances of nuclear isotopes, and he proposed a method using gaseous counterflow in a Holweck molecular vacuum pump. With the discovery of uranium fission he recognized the importance of enrichment of ^{235}U and enlisted colleagues from the Harvard chemistry department George B. Kistiakowsky and E. Bright Wilson in pursuing such a project. A trial experiment with argon gas confirmed their expectations, but when they sought to gain the interest of officials in Washington in 1940, they were told to forget it, that classified work was going on, and "the situation [was] well in hand."

THE WAR YEARS

As Europe became embroiled in World War II and with the resulting recognition of a need for increased military preparations in the United States, an exchange of military technical secrets with the beleaguered British was undertaken. This was the subject of the Tizard Mission from Britain in September of 1940. A major element of the exchange turned out to be a demonstration by the British of the newly developed pulsed-cavity magnetron, which produced many kilowatts of peak power at a microwave frequency near the 10-cm wavelength. The members of the microwave subcommittee, chaired by Alfred Loomis of the National Defense Research Committee, were so excited by the demonstrated performance that they undertook almost overnight to establish a special laboratory to develop microwave "radar" around it. Kenneth Bainbridge was the first scientist not already involved with the committee to be recruited (by E. O. Lawrence) to the laboratory, which became the Radiation Laboratory at the Massachusetts Institute of Technology. On a leave of absence from Harvard, he spent more than two and one-half years on that project, during a part of which, in the spring of 1941, he participated in a mission to Britain.

In wartime activities that involved close collaboration with parallel projects in Britain, Ken's friendship with British physicists, especially with Cockroft, who had been a scientist member of the Tizard Mission, was an asset. On his visit he gained information about not only the radar program but also learned of British progress toward releasing nuclear energy while attending a meeting of the Maud Committee, which was overseeing that effort in Britain. Ken's particular project at the Radiation Laboratory was the push toward higher-powered radars, especially for the Navy. He found the Navy at that time the most technically oriented of the

U. S. military services and the least handicapped by protocols related to military rank. This experience was reflected in his concern about the organization of Los Alamos, where he was recruited in May of 1943, which operated under the Manhattan District of the U. S. Army and General Leslie R. Groves. The Bainbridge's two daughters Joan (Bainbridge) Safford and Margaret Tomkins (Bainbridge) Robinson were born in Cambridge, Massachusetts, well before the family moved to Los Alamos.

At Los Alamos early in 1944, at the request of George Kistiakowsky and Director J. Robert Oppenheimer, Ken undertook the oversight of the design of high explosive assemblies and preparations for a full-scale test of a nuclear bomb. In articles in the *Bulletin of the Atomic Scientists* (1975), he lucidly described the search for an appropriate site, the preparations, and the successful carrying out of the test early in the morning of July 16, 1945. He titled the second of those stories "A Foul and Awesome Display." His remark to J. Robert Oppenheimer immediately after the event—"Now we are all sons of bitches"—marked the beginning of his dedication to ending the testing of nuclear weapons and to efforts to maintain civilian control of future developments in that field.

RETURN TO ACADEMIC LIFE

In the fall of 1945 Ken was at last free to return to academic science at Harvard. He undertook then to build a large mass spectrograph, designed for high resolution of masses and to replace the prewar cyclotron with a much more powerful one utilizing the then newly invented concept of synchronous acceleration. The relativistic increase of effective mass as the protons gained energy was compensated by sweeping the radio frequency down appropriately during an acceleration cycle. The latter project was handed over to Robert R. Wilson, who had joined the physics department at Harvard after the end of the war. Wilson, however, was recruited to head the large nuclear physics group at Cornell after residence at Harvard for just one semester. Norman F. Ramsey was then recruited to the Harvard department and assumed responsibility for managing the construction of the new cyclotron. Its design had been completed before discovery of the pi meson as the particle mediating nuclear forces. The energy of the new synchrocyclotron turned out to be just less than required for pion production. For about a dozen years the new Harvard cyclotron was employed for many scattering experiments and other studies of nucleon-nucleon forces and of nuclear structure. The operating life of the cyclotron was greatly extended when it became a facility for research on the use and clinical applications of the highly focused proton beam in collaborative projects with staff members from the Massachusetts General Hospital. It will be shut down finally in the late 1990s, when its role will be taken over by an even more powerful dedicated machine at the hospital, enabling further expansion of the important clinical applications developed using the physics cyclotron.

Ken devoted much of his energy just after the war to designing for the Harvard physics department an advanced laboratory in nuclear physics intended as a course of study for graduate students. Because of the many new students underwritten by the GI Bill, the number of graduate students in physics was far greater than had been the norm before the war. Nuclear physics had gained new visibility and popularity from its contributions to winning the war. Students gained their first experience in activities preparing them for research in experimental physics in Ken's meticulously designed and documented laboratory. The experiments ranged from a replica of J. J. Thompson's positive ray apparatus (a precursor of mass spectrographs) through a bent crystal X-ray spectrograph, a 180° beta-ray spectrograph using the then new technique of NMR for field calibration, to analysis of tracks in photographic emulsions to identify muons. As a part of Ken's dislike of the development and testing of nuclear weapons, he set up a facility associated with his laboratory of nuclear physics to collect and measure radioactive fallout. In his own research he built balanced ionization chambers with which he was able to determine changes in lifetimes of several long-lived isomers, which decay by internal electron conversion when their atoms are differently bonded chemically or are subjected to physical compression. In addition to constructing his large mass spectrograph to make precise measurements of mass differences among pairs, he built an elegant double-focusing electron spectrograph. In the years before his retirement in 1975, Ken devoted much of his time to improving the graduate student advanced laboratory and to developing a similar version for advanced undergraduates. Among his other contributions to teaching were lecture courses on nuclear physics, mainly for graduate students.

From 1950 to 1954 Ken served as chairman of the physics department at Harvard. This was a time marked by the vicious attacks on certain members of academia, and especially at Harvard, by the House Un-American Activities Committee and a committee of the Senate dominated by Senator Joseph McCarthy. Ken gave generously of his time and energy overseeing the relationship between the university administration and one of our colleagues who became a prime target of these attacks.

Two legacies of Ken's years as chairman were a renovation of a part of the then seventy-year-old Jefferson Physical Laboratory and the establishment of the Morris Loeb Lectures in Physics. Both were enabled by use of a part of a newly available endowment fund, which had been held in trust for many years. Thus the Morris Loeb endowment was shared between the chemistry and physics departments. A characteristic of Ken's style of work in his developing of instruments, lecturing in courses, research, and administrative activities was a meticulous documentation and keeping of records, habits of enormous help to his successors in all those projects.

In the late 1950s Ken was one of the first members of the Harvard faculty to participate in a new academic exchange program with the Soviet Union. Harvard's sister university was designated to be the University of Leningrad. Almost concurrent with his arrival in Leningrad there occurred the incident of the crash of the RB72 reconnaissance plane somewhere off Murmansk, which threw a difficult shadow over his relationship with his Soviet hosts, but the tension relaxed during the course of his stay.

In June 1975 in his last year before his retirement, Bainbridge was enlisted to serve on a joint Iran-Harvard planning commission to design Reza Shah Kabir University for Iran. Ken and his Harvard colleagues made visits to Iran, however this project was short lived because of the political upheaval and expulsion of the Shah from Iran.

Ken's years in Los Alamos and Alamogordo, New Mexico, provided him an opportunity to indulge in his long established amateur interest in mineral crystallography, a source of great pleasure. He had always enjoyed outings in the mountains, even in New England, to collect specimens, and New Mexico brought a much expanded dimension to that interest.

In January 1967 Ken suffered a tragic loss when his wife Margaret (Pitkin) Bainbridge, the mother of his three children, died suddenly at their home in Watertown, Massachusetts, from a blood clot associated with a recently fractured wrist. Ken, Peg, and their children had formed a great attachment to the island of Martha's Vineyard, where they had spent many of their summers as tenants in a cottage in Chilmark overlooking Chilmark Pond just below Abel's Hill. They had finally been able to buy a piece of land there and had just completed their own summerhouse the year before Peg's sudden death. That beautifully situated house was designed and constructed with the same careful attention to detail that exemplified all of Ken's personal and professional activities. His daughters have described instructions he left for the continued upkeep of the house, especially its extensive deck, adding that a supply of the needed materials was stored in the basement. Peg, their son Martin, and finally Ken were all buried in a plot in the small historic cemetery on Abel's Hill overlooking their house below. I (R.V.P.) am grateful to Ken for also introducing my wife and me to the beauties of the island as long ago as 1950, where we, too, were able to spend several happy holidays.

In October 1969 Ken married Helen Brinkley King, an old friend then serving as an editor for the William Morrow publishing house in New York City. She, as well as his son Martin Keeler Bainbridge, predeceased him. He is survived by his two daughters Joan Bainbridge Safford of Evanston, Illinois, who is deputy United States attorney for the northern district of Illinois, and Margaret Bainbridge Robinson of Cleveland Heights, Ohio, who is dean of undergraduate studies at Case Western Reserve University, and five grandchildren.

CONCLUSION

Kenneth Bainbridge contributed extensively to the development of the field of nuclear physics during his many active years. Especially notable were his several designs of mass spectrographs and their many applications to the study of nuclear isotopic masses and energy-mass equivalence. Other important contributions to nuclear physics were his early construction of cyclotrons and his discovery of the effect of chemical states on nuclear decay rates. During World War II, as the first recruit to the MIT Radiation Laboratory, he made major contributions to the microwave radar program of the Allies and then moved on to Los Alamos, where he oversaw the preparations and carrying out of the first test nuclear explosion. He was a strong advocate of civilian control of nuclear developments and devoted time and energy to efforts to restrict any first use of nuclear weapons by the United States. Bainbridge, as a teacher, introduced many students to the science of physics, especially nuclear physics, through his lecture courses and his advanced laboratory. He was a careful designer and painstaking keeper of records. The work of his colleagues and his successors in the enterprises he had developed gained enormously from his pioneering contributions, detailed designs, and meticulous record keeping. He was a model of personal and scientific integrity and a personal friend who is much missed.

Kenneth Bainbridge was awarded the Levy Medal of the Franklin Institute in 1934. He was elected a fellow of the American Academy of Arts and Sciences in 1937 and a member of the National Academy of Sciences in 1946. He was the recipient of two letters of commendation from General Leslie R. Groves for his work on the Manhattan Project and the Presidential Certificate of Merit for his services as staff member of the MIT Radiation Laboratory,

ESPECIALLY HELPFUL sources for this memoir were an interview of K. T. Bainbridge by John Bryant published as "*Rad Lab: Oral Histories Documenting World War II Activities at the MIT Radiation Laboratory*" published by the IEEE in 1993 and the Bainbridge articles in the *Bulletin of the Atomic Scientists* cited in the bibliography (1975).

NOTES

1. K. T. Bainbridge and others. Jabez Curry Street 1906-1989. In *Biographical Memoirs*, vol. 71, pp. 346-55. Washington, D. C.: National Academy Press, 1997.

2. Photo-electric tubes, patent no. 1,901,577; method of preparing photo-electric tubes, patent no. 1,901,578 (British patent no. 303,476).

3. A method of amplifying photo-electric currents by means of secondary emission from an auxiliary cathode, patent no. 2,206,713.

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