NATIONAL ACADEMY OF SCIENCES

WALKER BLEAKNEY

1901—1992

A Biographical Memoir by

GEORGE T. REYNOLDS

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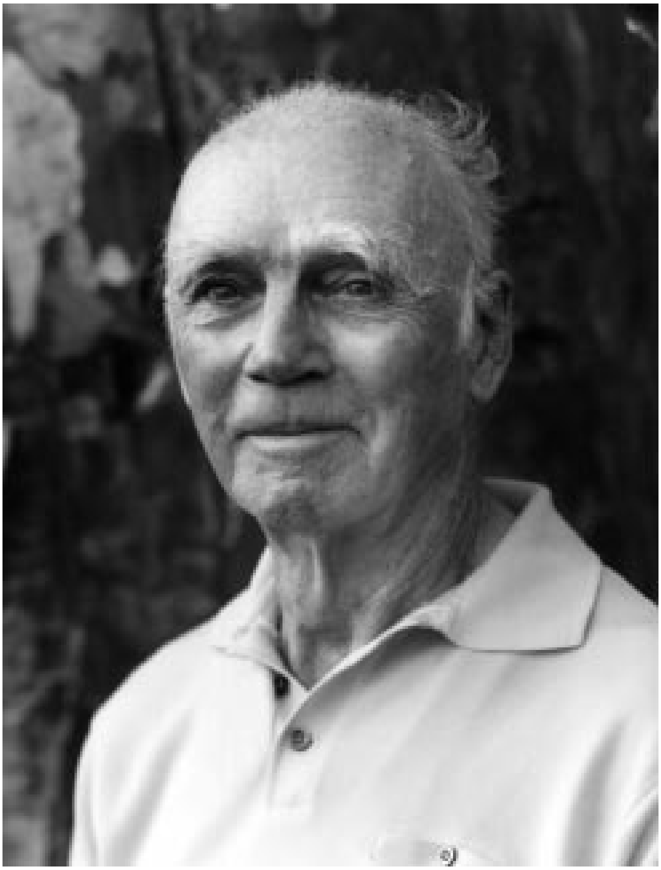
NATIONAL ACADEMIES PRESS
WASHINGTON D.C.



Photograph by Jacqueline McBride, Santa Barbara, California

Walker Bleakney

WALKER BLEAKNEY

February 8, 1901–January 15, 1992

BY GEORGE T. REYNOLDS

WALKER BLEAKNEY, THROUGHOUT a career devoted to experimental physics, has left a legacy of respect and appreciation among his many students and colleagues. He possessed a remarkable combination of intuition and laboratory technique that resulted in significant contributions in several diverse fields. Along with these professional attributes, he had a sensitivity for his students and associates that earned him respect as a humanist as well as a scientist. These qualities also made him a successful administrator in the Princeton University physics department during a period of transition in the scale of research and teaching activities, as well as the construction of a new physics building.

Bleakney was born in a farmhouse in Armstrong County, Pennsylvania, a few miles from the tiny village of Elderton. His parents were farmers who had left school at the fifth grade, believing that the basic abilities to read, write, and do sums were all the education necessary for their chosen life. When Bleakney was six years old, the parents and their six children moved to a farm near Milton, Oregon, and then to another near Echo, Oregon. These moves were significant in Bleakney's education, since they resulted in his spending three years in the second grade, a situation he did not particularly regret at the time. In his own words, "the work had become rather easy by the third year."

His boyhood experiences did much to develop his self-reliance and mechanical abilities, traits that served him well in his laboratory career. He knew the demands and satisfaction that come with hard physical labor. His determination to secure an education was tolerated by his parents so that he was able to complete high school (as the only boy in a graduating class of four), an accomplishment that required a fourteen-mile round trip on horseback over a ridge "too dry to farm and too high to irrigate."

Determined to continue in college, Bleakney took a year out to earn money.[1] This provided him experience in the fields of Oregon harvesting wheat behind a team of twenty-seven mules. He recounted with pride in later years that during this period his pay was 30% higher than the average field hand's because he had learned to handle wheat sacks so skillfully that he could tie the ear of the sack, roll the seam, put in fifteen stitches, tie the other ear, dethread the needle, and rethread it ready for the next sack in twelve seconds. Since the wheat came out at about three sacks per minute, this left him eight seconds to dump the sack in a straight line for later pick up. This quantitative analysis of his achievement was typical of him. Bleakney never lost respect for people who could do things with their hands, an attitude appreciated by his subsequent graduate students who might not be slated for outstanding careers in theoretical physics. At the end of that year, with about $1,000 saved to start college, he entered Whitman College in Walla Walla, Washington, as a member of the class of 1924. Here he worked his way through odd jobs that included firing furnaces and peeling potatoes at a hotel as pay for his dinner. He was also able to win letters in football and track.

As an undergraduate Bleakney majored in physics. Here he had a remarkable physics teacher, Benjamin H. Brown (the Oersted medalist of the American Association of Physics Teachers in 1939), and unusual classmates. The four physics majors in the class of 1924 were Bleakney, Walter Brattain (co-discoverer of the transistor and Nobel laureate), V. Rojansky (author of an early quantum mechanics text), and E. J. Workman (for more than twenty years president of the New Mexico Institute of Mining and Technology in Socorro).

In the spring of 1924 Bleakney and Rojansky were encouraged to take a competitive examination offered by Harvard University for a $1,000 scholarship for graduate work in engineering. Until this time, Bleakney had assumed that he would go back to farming, but when the results were announced, it turned out that he had won the scholarship (Rojansky was second). A year at Harvard in electrical engineering convinced him that research in physics was more appealing. At the time, the large Midwestern state universities offered the best opportunities for a student to earn his way while engaged in graduate study, and Bleakney found an opportunity to enter the University of Minnesota in 1925. After receiving his Ph.D. in 1930, he went to Princeton University as a National Research Fellow and two years later became an instructor of physics, thus beginning thirty-seven years of service to the department and university. He was named Cyrus Fogg Bracket Professor of Physics in 1953 and Class of 1909 Professor of Physics in 1963. He was a highly respected chairman of the department from 1960 to 1967, which were years of significant transition and changes.

Bleakney's research in physics divides distinctly into two time periods: 1925 to 1940 and 1940 until his retirement in 1969. His graduate work at Minnesota was under the general guidance of Professor John T. Tate. His doctoral dissertation was published in the form of two papers in *Physical Review* in 1929 and 1930 and initiated the period during which he investigated critical potentials and ionization products primarily in gases, as well as isotopic properties and the relative abundance of isotopes. In 1939 the outbreak of war in Europe caused many physicists, including a significant number at Princeton, of which Bleakney was one, to consider the contributions that physicists could make to the Allied cause. A group within the National Academy of Sciences obtained a small fund from the Army Corps of Engineers to form the Committee on Passive Protection against Bombing (CPPAB). By the autumn of 1940 Bleakney was recruiting colleagues and graduate students to participate in the research that ultimately led to his postwar research in fluid dynamics, notably in studying the physics of shock waves.

In the prewar period Bleakney made significant contributions to the field of molecular physics in the area of instrumentation development, as well as by the performance of key experiments focused on studies of critical potentials for the ionization of gases. Although he did not label it as such for several years, the technique he used was the mass spectrograph, an instrument that he was to improve markedly in the mid-thirties. As early as 1916 A. J. Dempster had developed a method of determining the masses of various atoms and molecules, followed by improvements by F. W. Aston, all of which led to more precise measurement of atomic and isotopic masses. Bleakney began a program at Minnesota, developing instruments of increased resolution and precision, which he continued to carry out at Princeton. There his National Research Fellowship was to allow him to work with K. T. Compton, but just as Bleakney arrived Compton left for MIT. As he described it in a later brief autobiographical note to an ex-graduate student, "Compton's leaving left a very big hole in the department . . . Smyth, Turner, Shenstone, Condon, and Robertson were associate professors, I believe. Of these Harry Smyth was the closest to my interests and became my nominal advisor. But, bless him, he was not a dictator. . . . Harry was helpful when needed, interested in my work, but made no effort to direct it. This was just great for me. I could freely follow my own interests. I cannot imagine a finer environment that those early years at Princeton."

As a later graduate student of Walker Bleakney (1940-43), I can attest that these same qualities as an advisor made him appreciated and respected by all those fortunate enough to have him as a mentor. Bleakney's program at Princeton throughout the 1930s was directed to improvements in the mass spectrometer in the areas of precision, resolution, and sensitivity. He was successful in all of these efforts and became recognized for his experimental skill. These contributions were not merely for the sake of technique, however; they were the result of his desire to explore important problems in the physics of atoms and molecules. As a result, more than thirty papers were published in journals and sixteen papers were presented at meetings during this period, describing studies of the isotopes of elements ranging from hydrogen to platinum and ionization products of organic molecules. Much of his research during this period concerned hydrogen, and he later remarked that he felt one of his most important contributions was the confirmation of the existence of deuterium, the determination of its abundance, and other chemical properties. His work also provided some of the first reliable evidence for the abundance of tritium in ordinary hydrogen and confirmation that ^3H may be unstable. In early 1938 he published a paper describing the design of

"A New Mass Spectrometer with Improved Focusing Properties" and a description of initial results of the application of an early model to the mass spectrum of ethane. His arrangement of crossed electric and magnetic fields resulted in ion paths that were trochoidal when projected in the plane perpendicular to the magnetic field and provided "perfect focusing properties." The paper ended with the optimistic statement: "It is hoped that a much larger apparatus will be completed in the near future." It was to be the superior mass spectrometer of the times. During this period of development, seven graduate students received their Ph.D.'s under his direction, all of them going on to successful careers in physics.

My arrival at Princeton for graduate work was in anticipation of joining in the final stages of completing this larger model and its application to the determination of certain atomic constants. World War II, however, abruptly changed the direction of Bleakney's research interests. With a small fund the National Academy of Sciences set up the CPPAB. H. P. Robertson, a professor of mathematical physics at Princeton, became involved early on and recruited Bleakney to join in as an experimentalist in an effort to determine the fundamentals of armor and concrete penetration by projectiles. A literature search soon showed that there was little or no experimental data on the subject.

Bleakney, anxious to gain some hands-on experience and to have some reliable data, decided to do some model tests on the penetration of bombs into concrete. As one of the first two graduate students recruited, I was able to witness firsthand his ability to "make do" with the meager facilities available. He had been given the magnificent sum of $50 to get started. With this he purchased an old military flintlock gun (he wanted a large bore) to use for firing model bombs into concrete and to study the penetration of missiles through steel. For the studies in concrete, arrangements were made with the civil engineering department to permit him to mix concrete and have it cured according to his specifications. The sample was in the form of a cube, one foot on a side. He wanted to purchase a wheelbarrow to transport the concrete cube from the engineering building to the physics laboratory, but so much of the $50 had been used in the purchase of the gun (and railroad fare to New York to secure it) that he could afford only a small wagon. The work was classified "confidential," so a camouflage cover was draped over the concrete during transport. For the studies of armor penetration, a double pendulum system was designed and built. (A subsequent patent on the system led Bleakney to say that we had a patent on the conservation of momentum.)

By early 1941 the need for fundamental knowledge in the field of military weapons was clear. Bleakney, together with Smyth, determined to initiate research on terminal ballistics on a larger scale. The newly formed National Defense Research Committee accommodated such an effort and provided a source of funds. As part of Division 2, the Princeton University Station was established with Walker Bleakney as its director. He proceeded to establish a program with personnel suitable for theoretical investigations, relevant laboratory experiments, and full-scale field tests. For this purpose he recruited a team of two architects, two field engineers, several theoretical physicists, an electronics engineer, and a small number of graduate students. Under his direction, blast measurements were made and correlated with damage to a number of buildings constructed for the purpose at Edgewood Arsenal. These measurements, which used full-scale bombs, taken together with small-charge blast measurements made at Princeton, provided confirmation of scaling laws useful in application to strategic bombing. Another major full-scale program was conducted at Camp Gruber, Oklahoma, in which underground blast measurements were correlated with damage to concrete structures similar to the pillboxes that would be encountered during the invasion on the Normandy beaches.

Blast pressures were measured by means of piezoelectric gauges. Under Bleakney's direction, several important results were obtained early on, such as the verification of scaling laws and the first "open-air" demonstration of irregular reflections of blast waves at air-ground interfaces, named "Mach Reflection" by von Neumann, a consultant in the work (von Neumann later used these results to specify the height of detonation of the Hiroshima and Nagasaki bombs). To calibrate these gauges, a brass cylinder was constructed with a diaphragm that supported a pressure differential. When this diaphragm burst, the known pressure difference was recorded by the gauge and a calibration secured.

Bleakney and the mathematical physicist A. H. Taub recognized that the device produced a one-dimensional shock wave. Taub developed an equation that utilized the Rankine-Hugoniot relations describing the velocity and pressures involved in the shock wave that resulted from the bursting diaphragm. Taub suggested to me that his equation be checked quantitatively with the calibrated pressure gauges. I designed a three-inch diameter brass tube for the purpose, and a crude basis for the elegant postwar shock tube research at Princeton was established. Bleakney's direction and participation in this work has been described in detail by R. J. Emrich.[2] As the technique developed, the physics of shock waves was studied in steel tubes of larger and larger dimensions that were fitted with large optical windows, permitting the incorporation of interferometric observations for the analyses. Of the many elegant results of this program, the one that gave Bleakney the most satisfaction was an interferogram showing a compression wave growing steeper and steeper as it progressed down the tube until it formed a shock, thus confirming a sequence that for many years could only be imagined. Bleakney particularly enjoyed recounting experiments in which apparently difficult problems were solved by ingenious use of simple apparatus and an understanding of basic physics.

Bleakney's pioneering work with the shock tube technique led to similar activities in other laboratories in the United States as well as several in other countries. Consistent with his knack for finding simple solutions for difficult problems, his group at Princeton never grew large. As his own administrative responsibilities increased, members of the group left Princeton to engage in related activities elsewhere.

Although focused on shock wave research, Bleakney was interested in physics as a broad field. He was a fellow of the American Physical Society and a member of its council from 1958 to 1963. He was a member of the American Association of Physics Teachers and served on the editorial boards of *Physical Review*, *Review of Scientific Instruments*, *Journal of Applied Physics*, and *Physics of Fluids*. While still an active teacher, experimentalist, and departmental chairman, Bleakney pursued several hobbies, which included golf, bowling, flying, and dachshund breeding. He took several of these activities with him to Santa Barbara when he retired in 1969 and supplemented them with hiking in the mountains of Wyoming. He enjoyed physical activity, refusing to go to a retirement home, which he called a "finishing school." His interest in physics and experimental techniques persisted. In retirement he rigged up an apparatus to take flash photographs of his golf swing and of his club striking the ball in an effort to understand better the correlation between the shape of the ball and the hook. He took great pride in physical activity, accepting the use of a golf cart only reluctantly. A few months before he died, he fell from a ladder while making alterations in a community shop for craft work.

Bleakney had an unfailing sense of humor. His anecdotes of his early life on the farm, with all the misadventures, his early school experiences, and various research endeavors during the war years provided amusement on the several occasions at which he was honored. He was indeed an accomplished storyteller. Students were always welcome at his home, where they were assured of the warm hospitality of his wife Tommie (nee Dorothy Clyde Thomas), who survived him until her death on December 30, 1995.

Walker Bleakney was elected to the National Academy of Sciences in 1959. He was the recipient of the honors listed below. He is also honored in the memories of his students and colleagues as a wise mentor and outstanding physicist. He was appreciated as well for his modesty and sense of humor. One of his many lasting contributions to the Princeton University physics department was his gift of a large, tastefully designed wastebasket (the "W. B. Waste Basket") strategically placed near the departmental mailboxes for the efficient disposal of junk mail. When he retired in 1969, more than 140 friends and colleagues, many of whom were former students, joined to pay him tribute. Many had benefited from his wise guidance and help, which he gave unselfishly to their research efforts. All benefited from having known a man with a zest for life and with outstanding human qualities.

AWARDS AND HONORS

National Research Council Fellow, 1930-32
Citations for World War II research
Honorary D.Sc., Whitman College, 1955
National Academy of Sciences, 1959
American Academy of Arts and Sciences, 1963
Cyrus Fogg Bracket Professor of Physics, Princeton University, 1953
Class of 1909 Professor of Physics, Princeton University, 1963

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1. W. Bleakney. Reminiscences of my youth in Oregon. *Am. J. Phys*. 40(1972):953-59.
2. R. J. Emrich. Walker Bleakney and the development of the shock tube at Princeton. *Shock Wave* 5(1996):327-39.

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1951

With C. H. Fletcher and A. H. Taub. The mach reflection of shock waves at nearly glancing incidence. *Rev. Mod. Phys.* 23: 271-86.

1954

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