NATIONAL ACADEMY OF SCIENCES

PAUL DARWIN FOOTE

1888—1971

A Biographical Memoir by

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Paul D Foote

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March 27, 1888–August 2, 1971

BY ALLEN V. ASTIN

PAUL DARWIN FOOTE was a man of diversified interest and talent who left a major imprint on many areas of science and technology. During his college days he started out to be an electrical engineer, was once tempted to become a lawyer and another time to be a classicist, but ended up with a major in physics. About 18 years before his death he gave the Home Secretary of the National Academy of Sciences the following account of his origins and youth.

I was born March 27, 1888, in Andover, Ashtabula County, Ohio, and was one of the first children in the county to be issued an official birth certificate. My father at various times was a city and county superintendent of public schools in Andover, Madison, Chardon, and Jefferson, Ohio. Upon his retirement from teaching at 65, he became general agent of several northeastern counties for an insurance company and was active up to his death in 1939 at the age of 87. My mother was Abbie Lottie Tourgee, who died at age 56 in 1920 from septicemia following a tooth extraction, this occurring long before medical knowledge of antibiotics. Both parents were for many generations of American extraction but originally Father's antecedents came from England and Mother's from France. Mother was talented in literary matters and was always active in women's clubs.

I had one brother, Ralph L. Foote, who was killed in an automobile accident in 1946. Our home life was most pleasant, one of our diversions being horseback riding and carriage driving. As a boy I always had my horse as well as a bicycle, and enjoyed many excursions with the children of other families. However, my home life terminated in 1905 at the age of 17, for thereafter I was able to return infrequently for only a few days.

I attended Chardon public schools from 1893 to 1905, being graduated as valedictorian of my class. Avocations were chess, fishing, and music. I played the clarinet in the school orchestra and village band from age 12; later with college orchestras and bands, and during the early Twenties with the Washington D.C. symphony orchestra.

As a youngster from 12 to 17, I was general agent for three Ohio counties for the sale of aluminum combs. Few people in the late Nineties had ever seen this metal, and the combs—priced at 10 to 80 cents—sold readily by mail and house canvass. It was a lucrative business for a boy and permitted me to indulge in many extravagances. For example, a classmate and I living about a mile apart had the first two-way radio telegraph setup in Ohio, around 1900, when silver coherers were required as detectors. We also had x-ray equipment and fairly good basement laboratories for electrical experiments and photography. From age 12 to 15 I had won several prizes for photography in such national magazines as *Success* (that eventually failed to substantiate its name). As I was the only amateur photographer in the village, my services in this work were often used to advantage by real estate agents and property owners. My first experience in hydraulics occurred at the age of 14 in the high school physics laboratory where I had permission to work on week ends. I connected a water turbine to the compressed air line, and just had time to drop under the table when the blades and case embedded themselves in the walls and ceiling.

Although I could have received financial help from my parents, I worked my way through college. While attending Adelbert College, Western Reserve University, 1905–1909, I was employed part time by a Cleveland law firm and taught city night school, chiefly algebra. Life with the law firm was most exciting and several of the young lawyers, who later became judges, encouraged me during my three years' employment, to enter this profession. The firm was the official collector of bad accounts for the associated merchants and physicians of Cleveland. My first introduction to the petroleum industry occurred when, acting as a deputy constable, I served notice on a president of an oil company to appear in court in answer to a suit for an unpaid bill. He was a giant, and he attacked me with his fists, doing considerable damage. He was heavily fined in police court and later I filed suit for personal damages. When at the hearing it was discovered that I was only 19, our attorneys immediately withdrew the case as it might have had complications in my service as deputy constable. Collection of bad accounts and garnisheeing of wages in those early days was dirty and usually thrilling business for those who understood the procedures, but it enabled me to become personally acquainted with nearly every physician and grocer in Cleveland.

I was always interested in mathematics and physics, and planned to take the five-year course in electrical engineering in combination with the Case School of Applied Science. Shop credits were secured by summer class work at Case. However, after being graduated from Western University magna cum laude and Phi Beta Kappa, I accepted an offer to become a laboratory assistant in physics at the University of Nebraska and thereafter was trained in physics and mathematics rather than electrical engineering.

At Western Reserve, Professor Emerson, head of the English Department, tried to influence me toward English as a career. I enjoyed his private tutoring and even won the Early English Text Society Prize, a complete edition of English pre-Chaucer, a quite valuable set of books later donated to the University of Pittsburgh. However, the turning point in my career was undoubtedly due to Professor Whitman, head of the Department of Physics. In advanced studies at Reserve in both mathematics and physics, I was often the sole member of the class so that my training in general was by practical tutoring. Professor Smith tutored me in quaternions during my sophomore and junior years, and Professor Whitman and later Professor Montcastle in various subjects in physics. Professor Whitman believed in learning by experience. This was often costly in time but thoroughly rewarding. Once I constructed, in the machine shop, a rather complicated apparatus of brass assembled by soldering. For final cleaning I asked him if boiling in oil would be satisfactory. He suggested trying it, and I thereby learned to his amusement that the boiling point of oil was above the melting point of solder.

At Nebraska I spent two years, 1909–1911, with Professor C. A. Skinner using apparatus designed by Professor Brace. My thesis, published in *Physical Review* in 1912, contained data on the magnetic rotation of the plane of polarization and ellipticity of plane polarized light reflected from mirrors in a magnetic field. These data, including effect of strength of field and dispersion through the spectrum, still stand in the modern physical tables. While at Nebraska I continued studies with the Department of Mathematics and studied theoretical physics in quaternion notation under Professor L. B. Tuckerman. In 1911 I took the civil service examination for assistant physicist at the Bureau of Standards and received a mere passing grade. I knew that I had answered all the questions correctly in quaternion notation. Years later the person who marked my papers informed me that although he did not understand any of my mathematics, since I had failed to define the notation, I arrived at the correct answers and he marked my papers "Pass". Even this low grade was sufficient for appointment. *

* Paul D. Foote: Autobiographical Statement for the National Academy of Sciences, 1953, pp. 1–5.

Paul Foote's career at the National Bureau of Standards consisted of two separate periods: 1911–1916 and 1917–1927. During the first period he rose rapidly from a laboratory assistant to the Chief of the Pyrometry Section, in which position he carried on pioneering work in high temperature measurements and played a major role in the development of the pyrometer and automatic heat control industries, then in their infancy. Noteworthy among many publications in this period was a section on "Thermometry, Pyrometry, and Heat Conductivity" for McGraw-Hill's *Standard Handbook for Electrical Engineers* (1916). The pyrometry organization that Foote developed at the Bureau during this period has continued substantially unchanged for many years and achieved international recognition.

In 1916 Foote resigned from the Bureau of Standards to accept the position of assistant manager of the Fisher Scientific Company in Pittsburgh, at that time a small firm engaged in the manufacture of instruments for military use, especially telescopic gun sights. He shared in the invention of the F & F optical pyrometer and other temperature measuring equipment. The production of military instruments, as well as that of pyrometer and metallurgical equipment, had just become a successful manufacturing operation when the University of Minnesota asked that Foote be permitted to spend seven months at the University to deliver lectures and to establish a section on pyrometry in the Physics Department. The Fisher Scientific Company agreed to the arrangement and retained him as assistant manager, to handle business transactions by correspondence, during the period he spent at the University.

From the time he had joined the Bureau in 1911, Foote had taken graduate academic work in Washington, D.C., receiving credit for this work from various schools. This, together with courses taken at Minnesota, and a thesis on pyrheliometry, reporting work done jointly with the U.S. Weather Bureau, was accepted by the University of Minnesota in fulfillment of the requirements for the degree of Doctor of Philosophy in physics which was awarded in 1917.

The United States had entered World War I by the time Foote returned to the Fisher Scientific Company, and shortly thereafter, at the request of the Government, he was released for technical duty at the Bureau of Standards. At first he was engaged in various military technical projects, probably the most important of which was the organization and direction of the development of heat control processes for the manufacture of high-grade optical glass. This early work, along with the cooperative efforts of a large group of industries, private laboratories (including the Carnegie Geophysical Laboratory in Washington, D.C.), and government agencies, led not only to the successful manufacture of a fair grade of optical glass for use in World War I, but provided a cornerstone for the highly developed American optical glass industry as we know it today.

While he was at the University of Nebraska Foote began an important and long-lasting friendship with John T. Tate, who received his master's degree there in 1912. This friendship was renewed at the University of Minnesota, where Tate had come after receiving his doctorate under James Franck in Germany. Foote said: "Tate was one of my teachers, in fact all of the younger staff took courses under each other. Tate taught me statistical mechanics and the group, including Arthur Compton, Tate, McKeehan and Klopsteg were in my class on radiation theory." * Tate also came to the Bureau of Standards on temporary wartime assignment in 1917 to work in the Pyrometry section with Foote. Although both were primarily concerned with wartime problems, Tate, influenced probably by exciting new work he had observed in Göttingen in the spectral analysis of mercury and other metal vapors, interested Foote in beginning a study of atomic processes.

* Quoted in: "John Torrence Tate," *Biographical Memoirs,* 47:464. Wash., D.C.: National Academy of Sciences, 1975.

Following the war, Foote and one of his assistants, Fred L. Mohler, turned their attention increasingly to this then new field of atomic research. Although this field of work was beyond the scope of their organizational responsibilities for heat and pyrometry work, Bureau Director Stratton allowed Foote and Mohler considerable freedom (but without extra funds) to pursue their spectral studies of atomic processes.

Their work, which was described in one of the Bureau's annual reports as "Investigations in Electronics," included studies of the excitation and ionization potentials of simple molecules and the photo-ionization of alkali vapors. These findings provided important experimental support for the quantum theory of spectra. An important monument to their work was the well-known reference book *Origin of Spectra,* first published in 1922. About the time the book came out, the Bureau Director decided to give their work organizational recognition in its own right and he established in the Optics Division a Section on Radium, X-Rays, and Atomic Structure, with Foote as its chief.

Foote's interests were very broad, and conscious of the emerging importance of X-rays and radium, he dedicated some of his attention to the health hazards of radiation. Through contacts established with most of the leading hospitals and roentgenologists in the United States, the new Section initiated the standardization of X-ray dosages for therapeutic treatments and also set up standards for hospital X-ray installations and for the protection of operators and patients. The procedures developed were the foundation for modern X-ray practice. In 1926, at the request of Secretary of Commerce Herbert Hoover, Foote undertook a special mission to Europe to report on engineering and medical developments in X-ray and radioactivity. At the time practically all of the radium in America was measured and certified under Foote's direction, and it was he who presented a second United States gift of radium to his friend Madame Curie.

By 1927 more than seventy publications had been produced by Foote's new Section, and ever alert to new challenges, he began to consider leaving government service. He decided to accept the position of Senior Industrial Fellow on a new Fellowship on oil production technology established for its Production Department by the Gulf Oil Corporation at the Mellon Institute of Industrial Research in Pittsburgh, and he resigned from the Bureau in 1927. At this time practically no physicists were employed in the petroleum industry, since most of the technical work was conducted by chemists in the field of production, refining, and product development. Foote's immediate problem was the initiation of research on the application of physics to the discovery of oil fields and to the production of crude oil from these fields. His experience up until this time had been for the most part in academic type physics and he knew nothing about the petroleum industry and its problems. He spent the first two years studying the industry, traveling in the oil fields, and establishing in his own mind the problems presented in petroleum exploration and production.

In a short time this Gulf Fellowship on production had overflowed its limited space at Mellon Institute, and additional quarters were rented in office buildings to house a rapidly growing Geophysical Division under Dr. E. A. Eckhardt, who joined Foote in 1928. Eckhardt, also a former Bureau of Standards physicist, had already been engaged in geophysical work for another oil company. From that time on, the work expanded by leaps and bounds, and by the beginning of 1930 a large part of the Fellowship was transferred to the Gulf Production Company as a new Research Department occupying a new eighty-room laboratory building. The research staff numbered approximately ninety, and the work had expanded into all phases of oil field technology. Research activities continued to expand, and before long the Company was again renting space in other buildings in the area. The Research Department of the Gulf Production

Company became in 1933 the Gulf Research & Development Corporation, a full-fledged subsidiary of Gulf Oil Corporation. Foote was named Director of Research and Executive Vice-President of this Company and was elected to its Board of Directors.

By 1934 the various groups associated with the Research Laboratory had become so spread out geographically that it was decided again to bring them all together. To this end a tract of forty-seven acres was leased near Harmarville, Pennsylvania, sixteen miles northeast of downtown Pittsburgh, and three main laboratory buildings with a few small auxiliary buildings were erected there. The new laboratory was occupied in April 1935. By this time the Company had broadened the scope of its activities to include major research projects in refining, manufacturing, and sales and had become the centralized research organization for the Gulf Oil Corporation. Shortly after its inauguration the Harmarville staff comprised approximately 250 employees, with another 250 in the field engaged in geophysical operations. In 1936 the name of the Company was changed to the Gulf Research & Development Company, its present name. In 1945, Dr. Foote was made a vice-president of the Gulf Oil Corporation and the Gulf Refining Company. Under Foote's leadership the Gulf Research & Development Company became one of the most complete, integrated petroleum laboratories in the world.

Paul Foote retired from the Gulf Research & Development Company at the end of 1953, having reached the usual industrial retirement age of sixty-five. For the next four years he engaged in a variety of consulting activities. One of these was a temporary part-time position on the staff of the National Academy of Sciences as the coordinator of the Academy's advisory services to the Office of Ordnance Research. During this period he moved his residence from Pittsburgh to Washington.

In September 1957 President Eisenhower appointed him to the post of Assistant Secretary of Defense for Research and Engineering. Foote became very much involved in trying to improve the military research and development program and in increasing the effectiveness of the advisory Defense Science Board. However, before he had time to bring about many significant changes he was forced to retire (in October 1958) because it was discovered that he was past the age of seventy and that he had had fifteen years prior government service at the National Bureau of Standards (NBS). Foote was amused over the fact that Civil Service regulations made a roadblock of his NBS years to his desire to stay through the balance of the Eisenhower Administration. At the time of his second retirement Dr. Foote was awarded the Defense Medal for Meritorious Civilian Service for outstanding contributions to the National Defense.

Paul Foote did not long remain idle. In 1960 he was persuaded to take a part-time position with the National Academy of Sciences to supervise the Academy's advisory services to the National Bureau of Standards. The assignment involved the staffing, scheduling, and coordinating of about sixteen discipline oriented committees, corresponding to the primary organizational units of the Bureau. Foote's wide contacts with the scientific and engineering community, coupled with his great interest in the Bureau, enabled him to organize highly competent committees to work effectively with the Bureau during a period of rapid growth associated with the post-Sputnik atmosphere. The Bureau valued most highly Paul Foote's efforts. Failing health led to Dr. Foote's resignation from this activity at the end of 1965.

Throughout the remainder of his life Foote's primary professional interest was the American Philosophical Society, where he remained active on the Society's Research Committee and was also a regular attendee, with his wife Miriam, of the Society's meetings. He was elected to the Society at the relatively young age of thirty-nine (1927) and served at various times as Councilor, Secretary, and a member of the Class I Membership Committee. He died at his Washington home on August 2, 1971.

Paul Foote was very active in professional society activities throughout his career, and he received many honors. He was president of the American Physical Society in 1933, secretary of the Optical Society of America in 1920, and vice-president of the Washington Academy of Sciences in 1936. He founded the *Review of Scientific Instruments* and was its editor for ten years. He was editor of the *Journal of the Optical Society of America* for a similar period and an associate editor of the *Journal of the Franklin Institute.* He was chairman of the small group of physicists that organized the American Institute of Physics in 1931.

He was elected to the National Academy of Sciences in 1943. Other honors and activities include: The Outstanding Achievement Gold Medal from the University of Minnesota, 1951; honorary degree of Doctor of Science from the Carnegie Institute of Technology, 1953; the Pittsburgh Man-of-the-Year in Science Award from the Pittsburgh Junior Chamber of Commerce, 1953; the Pittsburgh Award for outstanding service to chemistry from the American Chemical Society, 1954; the honorary degree of Doctor of Science from Western Reserve University, 1961. During World War II, he served as a consultant to the Office of Scientific Research and Development and to the Research and Development Board, and he was a member of the Executive Committee for Antisubmarine Warfare. He was also a member of the Industrial Advisory Group of the Atomic Energy Commission, the National Science Foundation Advisory Committee for Minerals Research, the Army Ordnance Advisory Committee, and the National Advisory Committee for Astronautics.

An insight into Paul Foote's broader interests and into his light good humor can be gleaned from some of his writings. About 1920 he published anonymously in the Taylor Instrument Company house organ a paper on "The Temperature of Heaven and Hell." By making scientific deductions from descriptions of the states of various material substances as described in the Bible, Foote concluded that Heaven was hotter than Hell. The paper, or portions of it, are periodically reprinted—for example, in the journal *Applied Optics* (1972)—but all have attributed the paper to an anonymous source. Nevertheless, a copy of the original manuscript with Paul Foote's notations identifying himself as the author was found in his personal file after his death.

A second example is provided in his Presidential Address to the members of the American Physical Society in December 1933. In discussing the importance of science to American industry, he was critical of those who claim that scientists are motivated mainly by an altruistic search for truth and are not concerned with recognition or material reward. He protested the belief

> . . . that the true scientist is motivated solely by his spirit of curiosity, by his thirst for knowledge, and for the discovery of truth for truth's sake alone. For the benefit of the many academic scientists who believe this fiction I propose the following practical experiment. Let articles submitted to the *Physical Review* be carefully read by the editorial board and secure the sponsorship of the American Physical Society. Every approved paper will then be published anonymously with no possibility of determining the authorship or the institution from which the research emanated. Certainly nothing is lost to science in the anonymous publication of work sponsored by a competent editorial board. All the truth is there as before. If such a policy were adopted I believe we would have no publication problem on our hands, but assuming a few papers are received it would be interesting to observe the American Institute of Physics in its attempt to collect three dollars per page from each authors' institution.*

The final example is a serious-funny letter to the Editor of *Science* in 1964 on the subject "Noise." In the letter Foote laments the rapid increase in noise associated with modern living, chastises engineers and architects on their priorities, and con-

* *Review of Scientific Instruments,* 5 (February 1934): 57.

cludes: "Eventually the problem will be solved. However, by the time that the building industry and architects are educated to the requirements, most of us will be immune to noise, buried under six feet of sod." *

Paul Foote had a full personal life, enjoying immensely his family, his music, his cabin cruiser, his automobile, and his clubs and professional societies.

He was first married, in February 1913, to Bernice Claire Foote, a cousin, and they had two children, William Spencer and Charlotte Jane (Mrs. John M. Hallewell). Each of his children presented him with three grandchildren. Bernice died in 1939, and about a year later Paul Foote married Sophie Miriam Shanks Sage, a widow and daughter of Robert Lewis Shanks of Greenwich, New York, a jeweler and watchmaker. From this marriage Foote acquired two stepsons, Robert L. and Evan T. Sage, and additional grandchildren.

Paul and Miriam spent many weekends and occasional long trips on the water in their well-equipped cabin cruiser, first acquired in Pittsburgh and later moved overland to Washington for anchorage in the Potomac. This activity led to an interest in navigation which Foote studied with his characteristic intensity.

During Foote's second period at NBS he helped organize among fellow scientists a chamber music group for which his excellence on the clarinet was a real asset.

Paul Foote must be classified as a man whose impact covered many fields: basic science, especially the early growth of quantum physics; scientific instrumentation, especially thermal and photoelectric measurement; the development of the petroleum industry; the effective use of science by industry, national defense and other governmental agencies, and the more effective operation of professional societies, especially to deal with their publication problems.

* *Science,* 143 (January 10, 1964): 101.

At the time of Foote's death Frederick Seitz wrote:

With the death of Paul D. Foote on 2 August at the age of 83 U.S. physicists have lost one of their most important and creative links with the early history of the profession. . . . Few individuals in our time have been as dedicated as he was to the creation of relationships within the community of American physicists that would advance the role physics could play in our society. Our times call for more of the spirit that motivated Foote to explore new roles for the members of the physics profession.*

**Physics Today,* 24 (November 1971): 73.

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