NATIONAL ACADEMY OF SCIENCES

WILLIAM DAVID COOLIDGE

1873—1975

A Biographical Memoir by

C. G. SUITS

Biographical Memoir

Photograph courtesy of General Electric Research Laboratory

W. D. Coolidge

WILLIAM DAVID COOLIDGE

October 23, 1873–February 3, 1975

BY C. G. SUITS

TUNGSTEN, X-RAYS, AND COOLIDGE form a trinity that has left an indelible impression upon our life and times. The key word in this triad is Coolidge, for his work brought the element tungsten from laboratory obscurity to the center of the industrial stage and gave the X-ray a central role in the progress of medicine throughout the world.

William David Coolidge was born in Hudson, Massachusetts, near Boston, on October 23, 1873, and he died on February 3, 1975 in Schenectady, New York. His father, Albert Edward, was a shoemaker by occupation, but he supplemented his income by running a farm of seven acres. His mother, Martha Alice, was a dressmaker in her spare time.

Will attended a grade school about a mile from town, where one teacher presided over the six grades. He was a good student and was liked by his classmates. After school each day, as an only child of his parents, he had a regular routine of farm chores. This, however, left room for fishing (summer and winter), baseball, hiking, skating, and primitive skiing. Photography became a lifelong hobby, and during this period he built a basement darkroom and constructed his own camera, including the shutter.

After grade school Will attended Hudson High School where, in due time, he graduated valedictorian in his class of thirteen. En route, he quit school for a while and took a job in a local factory manufacturing rubber garments. After a few months he decided that this was not a very good idea, and he went back to school, where he caught up with his class without difficulty. He had assumed that, with very limited family financial resources, he would not be going to college at the end of the school year. His plans changed when a friend who had been impressed by his scholastic record and his mechanical and electrical aptitudes suggested that he might be able to obtain a state scholarship for MIT. He applied, the grant was awarded, and in the fall of 1891 he went to Boston to continue his studies.

At the time MIT was "Boston Tech" and consisted of three buildings that accommodated 1,200 students. The period was one of growing interest in science and engineering, and the opportunities for engineering graduates were numerous in industry. Except for the Military Academy at West Point, MIT was the only institution of learning then offering an engineering degree.

Will enrolled in electrical engineering, which included some chemistry and mathematics and a modicum of literature, modern languages, and philosophy, in addition to professional engineering courses. In the chemistry course he came under the instruction of Professor Willis R. Whitney, which turned out to be the start of a long and happy relationship. Will was an excellent student, especially in his laboratory assignments and in his practical shop work, and the shops at Boston Tech were better than anything he had ever seen before. To see what industry was like, he spent the summer between his junior and senior years at the East Pittsburgh plant of Westinghouse Electric. Illness kept him out of school for a year, so he graduated with the class of 1896.

By this time he sensed that engineering practice was not exactly what he wanted; he had a greater interest in his science studies and the research orientation of his laboratory work. He therefore took a position as an assistant in physics at MIT. During the year he became aware of the possibility of obtaining a fellowship that would permit graduate study in Europe. He applied and obtained a grant for the following year, and he selected Leipzig for graduate work, influenced by the counsel of Professor Whitney, who had done graduate work there, and by the presence of Professor Paul Drude at that institution. The scholarship would not cover all of the costs of European graduate study, but Will was able to obtain a loan from a friend.

Will arrived in Liepzig well in advance of the fall term, and he audited the physics lectures of Professor Gustav Wiedemann, who advised him not to formally register until the fall term in October. In the interim, he set out to improve his German by talking to German students at every opportunity, by avoiding contacts with English and American students, and even by attending German church services. He lived with a German family who gave him a constant opportunity to talk in German. All of this—board and room—cost $20.00 a month!

When the October term started, Will developed close relationships with Drude and Wiedemann. Both were interested in his research and often dropped in to see him and to discuss their progress. During vacations Will took short trips to Italy and Bavaria, where he covered every tourist opportunity at very low cost, taking photographs that he developed in an improvised darkroom in Leipzig.

In Will's second year at Leipzig, he became lecture assistant to Drude, which helped his finances and provided a new experience. Looking ahead to the time when he might finish his doctorate, he wrote to MIT concerning a teaching position there. Meanwhile his research had progressed well, and he started to assemble his dissertation, which was published later in *Annalen der Physik*.

One day during that winter, the celebrated Professor Wilhelm C. Roentgen visited Leipzig and the Physikalishes Institute. Drude's assistant—Coolidge—had a chance to talk with Roentgen and was much impressed by the experience. Will didn't know it at the time, but his later research would serve to provide the major embodiment for the practical usefulness of Roentgen's X-ray discovery.

Later in the second school year, Will decided that, with luck, he might complete his dissertation and tackle his doctoral examinations, the basic requirements for a degree, by late summer. In July he received high marks in all of his examinations and was awarded the doctorate summa cum laude.

His application for an MIT teaching position coincided with an opening in the Physics Department, so Will Coolidge was back in Boston for the fall term in 1899. The following year he became a research assistant to Professor Arthur A. Noyes of the Chemistry Department, where, to his surprise, he remained for five years. In an adjacent laboratory, he became reacquainted with Dr. Whitney, who was then commuting to Schenectady during the formative years of the new General Electric Research Laboratory there. To Coolidge's complete surprise, Whitney offered him a job. He visited GE and accepted the offer in 1905.

The new Research Laboratory was located in an ancient building in the Schenectady plant, and at that time the total employment was about thirty, including several MIT graduates. The new laboratory's growth rate was limited by the availability of people of the quality Whitney wanted. At that early period, persuading a university scientist that he might have a career in industrial research was not accomplished easily nor often. Whitney, however, was developing an academic atmosphere, including weekly research meetings where members reported upon their work and occasionally heard talks by invited scientists. The laboratory was also achieving a modicum of credibility and prestige in its industrial setting because of the success of its early work. Dr. Whitney's improvements in the lamp filament were coming to market at about the time Dr. Coolidge joined the laboratory. This lamp—called the GEM lamp—was about three times more efficient than Edison's lamp, and it alone more than paid for the company's investment in the Research Laboratory up to that time.

Dr. Coolidge was devoted to his research work, but not to the exclusion of social contacts. Letters to his parents at that time made it clear that he was enjoying his friendships with Dr. and Mrs. Whitney and numerous colleagues in the Research Laboratory, and that he had met a number of young ladies. One of these ladies was especially attractive, and on December 30, 1908 he married Ethel Woodward, the daughter of the president of a local bank, in Granville. A daughter, Elizabeth, and a son, Lawrence, were born to this marriage. Early in 1915 Ethel became seriously ill and died at the hospital in February of that year. Dorothy Elizabeth MacHaffie, a graduate nurse from Ellis Hospital, was engaged by Will to help his mother with the two children at home. Dorothy was a charming person and, about a year later, she and Will were married.

Lamp research and experimentation were proceeding apace in the U.S. and in Europe during that period, and it is not surprising that Coolidge caught some of the excitement. Welsbach, of gas mantle fame, produced a lamp with a filament of osmium. The powdered metal was extruded with a binder, then sintered and mounted in the bulb. The resulting lamp was extremely fragile. The same process was used with tantalum powder with similar results. Just and Hanaman, in Vienna, used the same process to produce a tungsten filament. The resulting lamp showed greatly improved light production, but the problem of brittleness remained.

Dr. Coolidge first got into the lamp filament problem by way of tantalum, but he quickly switched to tungsten. Meanwhile, General Electric purchased rights under the Just and Hanaman patent, and Dr. Whitney himself started making tungsten filaments by that method. Coolidge found that these sintered filaments would lose some of their extreme brittleness if they were passed through a rolling mill with heated rolls. This was the first clue that suggested that tungsten was not necessarily brittle under all physical circumstances. Coolidge's observation was a very important "foot in the door." After three more years of painstaking research on this intractable metal, a process was developed by means of which tungsten was made sufficiently ductile at room temperatures to permit drawing through diamond dies. Close control of working temperatures, of tungsten powder grain size, and of trace metal additions, particularly thorium, contributed to the final successful result.

Lamps made with ductile tungsten filaments appeared on the market in 1911, and they have dominated the lighting industry ever since. All of the numerous alternative lamp filament processes were abandoned. Needless to say, Whitney, Coolidge, and the new Research Laboratory gained great stature as a result of this work.

Another very important happening at about this time was the occasion, in 1909, when Irving Langmuir joined the new laboratory. He came from Göttingen by way of Stevens Institute, and his doctoral thesis had concerned heat transfer in gases at high temperatures. The lamp filament involved such processes, and Langmuir soon set up experiments that showed that the light output of Coolidge's new lamp could be doubled if inert gas replaced the high vacuum. This gas-filled lamp with a ductile tungsten filament was about ten times more efficient than Edison's lamp, and it soon became the standard of the world for indoor lighting. At about this time, Coolidge was appointed assistant director of the Research Laboratory. In 1914 he was awarded the Rumford Medal of the American Academy of Arts and Sciences, the first of a long series of medals and honors that marked his career (see appended list.)

The availability of tungsten as a workable metal was a new fact of industrial life that came from Coolidge's work, and the application to the incandescent filament was only the first use of this remarkable metal. Tungsten exhibits the highest melting point in the periodic table, extremely low vapor pressure, great mechanical strength, and many other unusual properties. Its application to a great variety of industrial uses proceeded apace. Because of its high melting point and good electrical conductivity, Coolidge explored its use as an electrical contact for switching devices. At that time plantinum was a favored material for electric contacts in telegraph keys, relays, and small control equipment. It was questionable whether tungsten would be suitable for this purpose because, unlike platinum, it oxidizes readily at high temperatures. For many types of contacts, however, tungsten performed very well and showed much greater contact life than platinum. Coolidge made a trip to Dayton to show the new contacts to Charles Kettering, who became very enthusiastic about tungsten for auto ignition contacts. Ever since, tungsten has been the material of choice for this application.

Roentgen had announced his discovery of X-rays in 1895, and this important event created worldwide interest, especially among medical men who saw the X-ray as a possible diagnostic tool. While Coolidge was still at Boston Tech, he worked with Dr. F. H. Williams, one of the pioneers in the medical application of the new tube, and Coolidge retained an interest in X-rays when he came to Schenectady in 1905. Perhaps it was the success of the replacement of platinum with tungsten in contacts that kindled a new interest in the X-ray tube, which then employed a platinum anode.

The early X-ray tube was full of gas and its operation was very erratic, even in the hands of a skilled practitioner. As Coolidge got into the X-ray tube study, he found that the three principal parts—the cathode, the anode, and the "vacuum" environment—were all sources of erratic performance. The gas was required to produce ions, which produced electrons by bombardment of a cold aluminum cathode. Langmuir was then in the midst of a comprehensive study of electron thermionic emission, and he found that he could get controllable electron emission from one of Coolidge's hot tungsten filaments in the complete absence of gas, in other words at high vacuum. Coolidge immediately installed a heated tungsten filament in an X-ray tube with a tungsten disk anode. This tube was heated and outgassed until all evidence of gas ionization disappeared. The tube became the first stable and controllable X-ray generator for medical and dental use, and it rapidly replaced the gas-filled tubes in this country and throughout the world.

Dr. Coolidge was in touch with many physicians and radiologists during the progress of his X-ray studies, and one of them, Dr. Lewis G. Cole of New York, was the first to have his office equipped with the new tube. He was extremely enthusiastic about the performance of this tube, and he soon sponsored a dinner in a New York hotel where Coolidge demonstrated the new tube to a large group of prominent radiologists. At this dinner, Dr. Cole christened the new generator the "Coolidge Tube," which was later adopted by the General Electric Company as the product name, and it has since been used widely by the medical and dental professions.

The success of the Coolidge Tube brought much recognition and many new honors to its inventor. It greatly expanded the use of X-rays, not only in dentistry and medicine, where therapeutic as well as diagnostic applications grew, but in industry, where they were being used increasingly for nondestructive testing. For many years following the introduction of the Coolidge Tube, Coolidge himself was in the midst of continuing refinement of this generator: to very high voltages for deep therapy applications, to higher power for industrial use, and to finer definition for improved diagnostics. To the end of his career he retained an intense interest in X-rays and their applications.

In 1917 it became evident that the involvement in World War I by the U.S. was unavoidable. The GE Research Laboratory and Dr. Whitney became increasingly concerned with the possible role they could play in such an event, and development of a submarine detection system was an obvious challenge. Allied shipping was being sunk at a far greater rate than it could be replaced, and some solution of this problem was urgently needed. The depth bomb was an effective weapon *if* the submarine could be located, which was the key problem.

Prior to the entry of the U.S. into the war, the GE Research Laboratory became involved in war work through the Naval Consulting Board, on which Dr. Whitney served. A joint attack on the problem of submarine detection was planned involving GE, the Submarine Signalling Company, and Western Electric. An experimental station was set up on the Mohawk River, near where the GE Research and Development Center was located years later. Coolidge soon found that sealed rubber binaural listening tubes provided excellent range of about two miles with an azimuth sensitivity of about five degrees. This device went into service on U.S. and British vessels as the "C" Tube—for Coolidge. A later version, the

"K" tube, developed a range of ten miles with an azimuth sensitivity of ten degrees. These devices permitted submarine chasers to clear the Mediterranean of submarines in the spring and summer of 1918 and were an important factor in the final outcome of the war. The Coolidge tube was adapted to a field X-ray unit for use in World War I, and it became a major medical tool in field hospitals, where many practitioners became acquainted with it for the first time.

In the period following World War I, the Research Laboratory under Whitney grew in stature and influence, both within the company and in the scientific community. Langmuir's work on electron emission and surface chemistry found many important applications, including radio broadcasting and reception. Albert Hull was one of three scientists (with Debye and Scherrer) to develop X-ray diffraction in crystalline materials. His studies of gas-filled electron tubes helped open up the field of industrial electronics. Coolidge continued to expand the usefulness of X-rays by the development of million-volt, high-power generators for medical therapeutic work and multiple industrial uses. The year 1932 was an important year for the laboratory, for Coolidge became director upon the retirement of Whitney, and in the same year Langmuir became the first American industrial scientist to win the Nobel Prize.

By the time World War II broke out, the appreciation of the role of science and technology in the national defense establishment was well developed, and through the leadership of Dr. Vannevar Bush, a massive national research and development program was mounted to aid the war effort. The Office of Scientific Research and Development identified the areas of opportunity; organized the effort in university, industrial, and government laboratories; and provided the necessary financial backing. Coolidge became involved in the atomic bomb investigation from the beginning as a member of President Roosevelt's Advisory Committee on Uranium. In 1940 Dr. A. O. Nier of the University of Minnesota and Drs. K. H. Kingdon and H. C. Pollock of the GE Research Laboratory isolated U235 for the first time, and showed that it was the fissionable isotope. This author became a member of Division 13 of the NDRC (microwave radar) and chairman of Division 15 (radio and radar countermeasures), and both subjects became active areas for the participation of the GE Research Laboratory in the war effort.

Coolidge had planned to retire about the time World War II began in Europe, but because of the pressure of wartime work he agreed to stay on beyond his normal retirement. At the war's conclusion he resumed his plans for retirement, and he proposed that I succeed to his position, which I did on January 1, 1945. In retirement, Coolidge retained an active interest in X-ray research. He continued to receive recognition in the form of awards and medals for the impressive work of his career, even through his one-hundreth birthday, and he continued the photography hobby that dated from his boyhood in Massachusetts.

Although some of the milestones in Will Coolidge's remarkable career have been suggested above, this biography would be incomplete without words of appreciation for his personal qualities, which were equally impressive. Kindness and thoughtfulness in dealing with friends and associates were attributes that were deeply imbedded in his nature. I doubt if anyone ever heard him raise his voice in anger. His modesty was almost embarrassing, and he always viewed the accomplishments of his associates more generously than they themselves. He was greatly beloved by everyone who was privileged to be associated with him, and in the world of science, including medical science, he was regarded with deep reverence, as evidenced by the unprecedented award from the University of Zurich of a Doctorate of Medicine.

Will Coolidge was blessed with remarkable health throughout his very active lifetime, and he retained a keen mind into his late nineties. He died on February 3, 1975, at the age of one-hundred-and-one. We revere his memory.

REFERENCES

Baxter, James Phinney III. *Scientist Against Time.* Boston: Little, Brown, 1946.

Birr, K. A. *Pioneering in Industrial Research.* Washington, D.C.: Public Affairs Press, 1957.

Broderick, John. *Willis Rodney Whitney.* Albany, N.Y.: Ft. Orange Press, 1945.

Coolidge, William D. "Autobiography." Typescript. N.Y.: Center for the History of Physics, American Physical Society.

Hammond, John Winthrop. *Men and Volts.* Boston: Lippincott, 1941.

Hawkins, Lawrence A. *Adventures into the Unknown.* N.Y.: William Morrow, 1950.

Liebhafsky, Herman. *William David Coolidge.* N.Y.: John Wiley & Sons, 1974.

Miller, John Anderson, *Yankee Scientist.* Schenectady, N.Y.: Mohawk Development Service, 1963.

Suits, C. Guy. *Speaking of Research.* N.Y.: John Wiley & Sons, 1965.

Suits, C. Guy, and Way, Harold E., eds. *The Collected Works of Irving Langmuir.* N.Y.: Pergamon Press, 1962. 12 vols.

Westervelt, Virginia Veeder. *The World Was His Laboratory: The Story of Willis R. Whitney.* N.Y.: Julian Messner, 1964.

HONORS AND DISTINCTIONS

MEDALS AND AWARDS

1914 Rumford Medal, American Academy of Arts and Sciences, for his invention of ductile tungsten.

1926 Howard N. Potts Medal, the Franklin Institute, in consideration of the originality and ingenuity shown in the development of a vacuum tube that has simplified and revolutionized the production of X-rays.

Louis Edward Levy Gold Medal, the Franklin Institute, for his paper on "The Production of High Voltage Cathode Rays Outside the Generating Tube."

1927 Gold Medal, the American College of Radiology, in recognition of his contribution to radiology and the science of medicine.

Hughes Medal, the Royal Society, London, for his work on the X-rays and the development of highly efficient apparatus for their production.

Edison Medal, the American Institute of Electrical Engineers, for his contributions to the incandescent electric lighting and the X-ray arts.

1932 Washington Award, the Western Society of Engineers, in recognition of devoted, unselfish, and preeminent service in advancing human progress.

1937 John Scott Award, the City Trusts of the City of Philadelphia, based on his application of a new principle in X-ray tubes.

1939 Faraday Medal, the Institution of Electrical Engineers of England, for notable scientific or industrial achievement in electrical engineering.

1940 Modern Pioneer Award, the National Manufacturer's Association, awarded to Dr. Coolidge as "A Modern Pioneer."

1942 Duddell Medal (18th), the Physical Society of England, in recognition of his invention of the Coolidge X-ray tube.

Orden al Merito, the Chilean Government, for his many services to civilization.

1944 Franklin Medal, the Franklin Institute, in recognition of his contributions to the welfare of humanity, especially in the field of the manufacture of ductile tungsten and in the field of improved apparatus for the production and control of X-rays.

1952 K. C. Li Medal and Award (first recipient), Columbia University, for meritorious achievement in advancing the science of tungsten.

1953 Henry Spenadel Award, the First District Dental Society, for distinguished and significant contributions to dentistry.

1963 Roentgen Medal, the Society of the Friends of the German Roentgen Museum, to individuals of Germany and other countries who have helped in the advancement and dissemination of Roentgen's discovery in both the scientific and practical aspects; or who have been of especial service to the German Roentgen Museum.

1972 Power-Life Award, Power Engineering Society of the IEEE, for his contributions to the science of X-rays, the medical profession, and the welfare of humanity.

1973 Schenectady Patroonship

Climax Molybdenum Wedgwood Medallion, for pioneering work leading to the invention of ductile tungsten and molybdenum.

William D. Coolidge Award, the American Association of Physicists in Medicine

HONORARY DEGREES

Doctor of Science, Union College, June 1927
Doctor of Science, Lehigh University, June 1927
Doctor of Medicine, University of Zurich, September 1937
Doctor of Laws, Ursinus College, October 1942
Doctor Honoris Causa, University of Sao Paulo, November 1945
Doctor Honoris Causa, National School of Engineering, University of Brazil, November 1945
Doctor of Science, Catholic University of Chile, November 1945
Doctor of Engineering, Indiana Technical College, May 1947

SOCIETY MEMBERSHIPS

National Academy of Sciences
American Academy of Arts and Sciences
Washington Academy of Science (Vice-President, 1931)
American Association for the Advancement of Science
American Chemical Society (Emeritus Status)

American Electrochemical Society
American Institute of Electrical Engineers (Fellow)
American Physical Society
American Institute of Chemists
Sigma Xi
American Philosophical Society
Edison Pioneers
Eta Kappa Nu (Eminent Member)

HONORARY MEMBERSHIPS

The American Roentgen Ray Society
The American Radium Society
The Radiological Society of North America
American College of Radiology
The Roentgen Society, of England
Société de Radiologie Médicale, de France
Nordisk Förening för Medicinisk Radiologi, Scandinavia
The Pan-American Medical Association
Société Française des Electriciens
Medical Society of the County of Schenectady
The Dental Society of the State of New York
The Franklin Institute
Brazilian Institute for Study of Tuberculosis
Brazilian Society of Medical Radiology
Paulista Medical Association
Chilean Society of Radiology
Faculty of Physical and Mathematical Sciences of the University of Chile
Faculty of Biological and Medical Sciences of the University of Chile
Argentine Electrotechnical Association
Sociedad Peruana de Radiologia
Sociedad Argentina de Radiologia
American Academy of the History of Dentistry
Odontological Society of Lyon, France

CORRESPONDING MEMBERSHIPS

Brazilian Academy of Science
National Academy of Exact Physical and Natural Sciences of Lima
Société Française des Electriciens

SELECTED BIBLIOGRAPHY

Dr. Coolidge published more than seventy papers. Some of the more important are listed below.

1903

With A. A. Noyes. Electrical conductivity of aqueous solutions at high temperatures. Proc. Am. Acad. Arts Sci., 39(7):163–219.

1908

With A. A. Noyes. The electrical conductivity of aqueous solutions. II. Original apparatus and method. Conductivity and ionization of NaCl and KCl up to 306 degrees. Carnegie Inst. Washington Publ., 63:9–55.

The electrical conductivity of aqueous solutions. III. Later modifications of the apparatus and method. Carnegie Inst. Washington Publ., 63:59–67.

1910

Ductile tungsten. Trans. Am. Inst. Electr. Eng., 29, part 2:961–65.

1914

A powerful Roentgen ray tube with a pure electron discharge. Phys. Rev., 2d series 2, no. 6:409–30.

1925

Modern X-ray tube development. J. Franklin Inst., 199:619–48.

High voltage cathode rays outside the generating tube. Science, 62:441–42.

1926

With C. N. Moore. Some experiments with high voltage cathode rays outside the generating tube. J. Franklin Inst., 202:721–34.

1931

With L. E. Dempster and H. E. Tanis, Jr. High voltage cathode ray and X-ray tubes and their operation. Physics 1(4):230–44.

1932

With C. N. Moore. Experimental study of cathode rays outside of the generating tube. Congress International d'Electricite, Section 1, Rapport no. 19, 18 pp. Also in: Gen. Electr. Rev., 35(8):413–17.

1942

The role of science institutions in our civilization. Science, 96(2497):411–17.

1945

A plea for more fundamental research effort. Science, 119(3082): 110–11.

PATENTS

Dr. Coolidge received eighty-three U.S. patents. Some of the more important are listed below.

1909	935,463. Dies and Die Supports.
1912	1,026,382. Metal Filaments.
	1,026,383. Metal Filaments.
	1,026,384. Metal Filaments.
1913	1,082,933. Ductile Tungsten.
1915	1,153,290. X-Ray Targets.
1917	1,211,092. X-Ray Tubes.
	1,211,376. Electron Discharge.
	1,215,116. X-Ray Apparatus.
1925	1,529,344. X-Ray Apparatus.
	1,541,627. X-Ray Apparatus.
	1,543,654. X-Ray Apparatus.
1939	2,181,724. Electrostatic Machines.