NATIONAL ACADEMY OF SCIENCES

COMFORT AVERY ADAMS

1868—1958

A Biographical Memoir by

VANNEVAR BUSH

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C. A. Adams

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November 1, 1868–February 21, 1958

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DR. COMFORT AVERY ADAMS was born in Cleveland, Ohio, on November 1, 1868. His mother was an intensive student of art and history, and for many years was president of the oldest Women's Literary Society in Cleveland. His maternal grandfather was a physician by profession, but with many avocations. He developed many complicated types of fireworks, was a horticulturist and floriculturist, and developed new types of fruit and flowers.

Dr. Adams' father lost all of his property during the panic of 1873 so the family was in rather straitened circumstances throughout his youth. Thus, although the family lived in a neighborhood of well-to-do people, his brother and he shared the work of taking care of a horse, a cow, chickens, and a considerable flower and vegetable garden. This amounted to about three hours daily while he attended school, and he attributed his good health to this physical work, done mostly out of doors.

He attended the public schools in Cleveland through high school. His teacher of physics at Central High School was a very remarkable man not only as a teacher but also in his standards of conduct and his ability to guide young men. His name was Newton M. Anderson, and it was under him that Dr. Adams got his first start in physics and soon became his as-

sistant. This start was so fundamental, sound, and excitingly interesting that it determined his life's work.

After high school he attended the Case School of Applied Science (now the Case Institute of Technology) and, on Mr. Anderson's recommendation, he was appointed assistant in physics to Dr. Albert A. Michelson. This appointment held for all four years. From him Dr. Adams learned much, notably in scientific discipline, in meticulous thoroughness in experimental work, and in sound thinking. He participated in the building of several interferometers, including the one employed in the Michelson-Morely experiment on ether drift in 1887. He also made several successful refraction gratings.

In 1890 he graduated from Case with a degree in Mechanical Engineering, since there was at that time no program in Electrical Engineering. After graduation he started his teaching career at Harvard University, a career which lasted from 1891 to 1936. When he retired he had held positions as Abbott and James Lawrence Professor of Engineering, Gordon McKay Professor of Electrical Engineering, and, in 1919, Dean of the School of Engineering.

During the three years, 1914-1917, when Harvard was cooperating with the Massachusetts Institute of Technology in the teaching of engineering subjects, his office was in the M.I.T. buildings. This cooperation, which he had helped to initiate, was stopped by a court ruling based on the will of the late Gordon McKay, who had left his estate to Harvard University for the teaching of engineering. At Harvard Dr. Adams early developed a keen interest in the theory and design of electrical machinery; in fact, it was his main interest for many years.

As a teacher he had a profound influence on a large group of successful men. His influence initiated a new approach to engineering problems. It consisted in an analytical design approach, where physical principles and mathematical analysis

are merged with experimental and practical design parameters or, as Dr. Adams called them, "design limitations." This merging of the two proceeded to a build-up of a complete "Design Schedule," wherein formulas are introduced in a most logical order, with constants or coefficients to account for the various parameters.

It was ten years before he began to write for publication, as he was interested more in the solution of a problem than in writing it up for publication. In the beginning, 1902-1904, he wrote a series of three articles published in the *Harvard Engineering Journal,* dealing respectively with alternator regulation, synchronous motors, and induction motors.

He sent a copy of the paper on synchronous motors to Professor André Blondel of the Ecole de Ponts et Chaussées in Paris, who was one of the foremost scientific engineers in France and the originator of the emf circle diagram. Professor Blondel was so pleased with the paper that he asked Dr. Adams to write two chapters of his book on synchronous motors, then in preparation.

Dr. Adams' work on induction motors continued, and the results were set forth in a paper presented to the International Electrical Congress at St. Louis in 1904. This paper closed a considerable gap between theoretical calculation and experimental tests, particularly in the case of two-phase motors, which were more common at the time. The following year he presented to the American Institute of Electrical Engineers a more general paper on this subject, including several original and more accurate methods of calculation and several new and instructive formulas, as well as a discussion of the general use of dimensionless parameters. In 1907 Dr. Adams presented a paper to the A.I.E.E., prepared in cooperation with two graduate students, which referred to the fractional pitch windings for induction motors. These papers, written nearly a half

century ago, are still classics of the induction motor art.

During the time he was consultant for Babcock and Wilcox Company he designed new machinery. Initially his work included the design of high-frequency steel melting furnaces, the largest of which had a capacity of 8000 pounds and was at that time the largest in this country if not in the world. In 1903 the American Tool and Machine Company of Boston, then the largest American manufacturers of sugar centrifugals, asked him to design a motor for direct connection to centrifugal machines. His design provided for doubling the output of each machine as well as improving the quality of the product. For some years after the introduction of these motors in sugar refineries, 95 percent of all the direct-connected sugar centrifugals in this country were of his design, as well as some in Cuba and Mexico.

At about the time of the entrance of the United States into World War I, Dr. Adams was appointed chairman of the Welding Committee of the Emergency Fleet Corporation to the end of applying the welding process in the building of ships with an accompanying reduction in cost.

An outcome of this work was the formation of the American Welding Society in April 1919. Dr. Adams was elected the first president, and a little later to honorary membership. Dr. Adams, realizing that the science and art of welding involved so many branches of technology that it had as yet a long way to go in the field of fundamental research, organized the American Bureau of Welding for research purposes.

Another result was the formation in 1935 of the Welding Research Council of the Engineering Foundation. Dr. Adams served as chairman from its inception until his retirement in 1949, when he was elected honorary chairman with the following citation: "In testimony of the deep appreciation of the Council for his foresight and wisdom in the creation of the

Council in the year 1935, for the quality of his leadership, for his services as the first Chairman for the years 1935-1949 and for his other and more recent valued contributions to its continued success."

Long before the organization of the Welding Research Council, Dr. Adams' consulting work for the Babcock and Wilcox Company included the development of the application of welding in the manufacture of boilers and pressure vessels. The major innovation was the first large-scale welding with alternating current. He designed the first transformers for a-c welding, which were used for some years thereafter, notably in welding the Boulder Dam penstocks, some of which were thirty feet in diameter and three inches thick. He also made several contributions to the welding art in his consulting work with the Edward G. Budd Manufacturing Company.

During World War I he was appointed a member of the General Engineering Committee, Council of National Defense, and shortly thereafter was appointed its chairman. One of his first problems dealt with anchor chain, which was then a very critical need. As it was made of wrought iron and hand forged, the number of artisans available was insufficient to meet the war demands. One of Dr. Adams' General Electric friends suggested that anchor chain might be cast interlinked, from the same steel used for railroad car couplings, which were heat-treated after casting. This worked out satisfactorily, and this type of chain was used on the carrier *Forrestal*, one link weighing about 350 pounds.

Another task undertaken by the General Engineering Committee was the standardization of the purchase specifications of about fifty different bureaus in the War Department. Under General Goethals as Chief of the Quartermaster Department, the reorganization was started.

Dr. Adams was elected to membership in the Boiler Code

Committee of the American Society of Mechanical Engineers, and was a member for twenty-odd years, resigning at the age of eighty.

In 1910 he was elected chairman of the American Institute of Electrical Engineers Standards Committee, then in its very early stages, and held this office for ten years. Some of the projects overlapped those of other engineering societies, so that it was apparent there was need for cooperation. This was finally accomplished in 1919, and Dr. Adams was elected first chairman of the American Engineering Standards Committee. In 1920 this committee was enlarged considerably and the name changed to the American Standards Association.

In 1919 Dr. Adams was elected chairman of the Engineering Division of the National Research Council on a full-time basis for the first year (on leave of absence from Harvard University) and on a half-time basis for the following year.

Another interesting assignment was the organization of the Highway Advisory Board. Automobile traffic was increasing in both volume and intensity so rapidly that roads often went to pieces before their bond issue matured. With the cooperation of industrial groups, the Board built several experimental sections of roads. Out of this research came contributions to the science of soil mechanics.

Having early discovered the great lack of scientific knowledge in the field of insulation and the need of research therein, Dr. Adams undertook to establish a cooperative agency to deal with this important problem. The final result of that effort was the "Conference on Electrical Insulation," which now has an annual three-day meeting attended by four or five hundred experts in this field.

On September 1-16, 1954, the International Electro-Chemical Committee held its Golden Jubilee in Philadelphia, its birth having taken place in St. Louis in 1904 at the Interna-

tional Electrical Congress. It was to this first Congress that Dr. Adams' paper on leakage reactance of induction motors had been presented. Fifty years later he was an honored guest at a reception as one of the two living scientists who addressed the group that founded this international organization.

In his consulting work with General Electric Company Dr. Adams designed a great variety of machines. In 1949 the Research and Development Department of the Franklin Institute asked his assistance in designing a very special motor for rotating the turret of a large battleship through a train of gears. Another of his consulting appointments was for the Okonite Company and the Okonite Callender Cable Company, for whom he worked nearly fifty years. During the last thirty years his work was mainly with the cable branch of the company. Part of his work, and to him perhaps the most important, was the teaching of the younger men connected with the laboratories.

In 1943 he delivered the first Adams Lecture to the American Welding Society. The citation reads: "The Adams Lecture was established in 1943 in honor of Professor Comfort Avery Adams, first president of the American Welding Society, in recognition of his outstanding leadership in the research and technical activities of the Society. He was one of the founders of the Society in 1919 and since that time has given generously of his time and wisdom to its development. He has received international recognition for his scientific contributions to the fields of welding and of electrical engineering. Dr. Adams has contributed greatly to the prestige of the American Welding Society in the engineering profession, due to his remarkable combination of human qualities and unusual scientific ability."

"For his contributions to the theory and design of a-c machinery and his work in the field of electric welding," the A.I.E.E. Lammé Medal for 1944 was presented to Dr. Adams

at the Institute's summer convention in Toronto. This was the thirteenth presentation of this medal, which was established by the will of Benjamin Carver Lammé. The medal was presented to Dr. Adams by Mr. Philip L. Alger, Fellow, A.I.E.E. The speech accompanying the presentation included the following: "Looked at in retrospect, his distinguished career is seen to have resulted naturally from his pre-eminence in the old-fashioned virtues of clear thinking, persistence, and absolute reliability. He has devoted his life to the advancement of engineering by unselfish aid to students and fellow engineers as well as by his own inventions. In so doing, Dr. Adams has earned a lasting place in the Hall of Fame of American Engineers, and he has also made a host of friends who will ever value the inspiration he has given them."

Dr. Adams was married in 1894 to Elizabeth Chassis Parsons, and had two sons, John and Clayton Comfort.

HONORS AND DISTINCTIONS

MEMBER

National Academy of Sciences
American Academy of Arts and Sciences
American Institute of Electrical Engineers
American Society of Mechanical Engineers
American Society of Civil Engineers
American Standards Association
American Engineering Council
American Society for Metals
American Society for Testing Materials
Society for Promotion of Engineering Education
Physical Society
British Institute of Electrical Engineering
Verband Deutscher Electrotechnikes
Société Française des Electriciens
Sigma Psi
Tau Beta Pi

CLUBS

Harvard Faculty Club, Cambridge, Massachusetts
Engineers Club, New York
Engineers Club, Philadelphia, Pennsylvania
Cedarbrook Country Club, Philadelphia, Pennsylvania

HONORS

Honorary Doctor of Engineering, 1925, Case School of Applied Science
Honorary Doctor of Engineering, 1939, Lehigh University
Oldest living past president of American Institute of Electrical Engineers
Lammé Medalist of A.I.E.E.
First president and oldest living past president of the American Welding Society
Honorary Member of the American Welding Society
Delivered the first of the series of Adams Lectures founded in his honor by the American Welding Society

Organizer and first chairman of the Welding Research Council, then honorary chairman
First recipient of the Samuel Wylie Miller Medal of the American Welding Society
Long-time member of the Boiler and Pressure Vessel Committee of American Society of Mechanical Engineers, then Honorary Member
Honorary Member of the International Acetylene Association
One of 35 engineering members of the National Academy of Sciences

TECHNICAL EXPERT

Law and patent cases—lost only one case
Boston subway explosion
Pitch dust explosion in Baltimore
Ohio State office building explosion
Arc lamp patent suit vs. General Electric Company
Johnson Double Insulation Testing of Live Lines
Several important patent suits in welding field

CONSULTING ENGINEER

Stone & Webster
American Tool and Machine Company
Warner Sugar Refining Company
American Sugar Refining Company
Boston Edison Company
Public Service Electric Corporation of New Jersey
General Electric Company
Okonite Company
Okonite Callender Cable Company
Babcock and Wilcox Company
Edward G. Budd Manufacturing Company
Also numerous transient jobs

OFFICES AND COMMITTEES

President, American Institute of Electrical Engineers, 1918
First President and Founder of American Welding Society, 1919
Director, American Bureau of Welding, 1919, 1935

Chairman of Welding Research Council, Engineering Foundation, 1935

Chairman, Division of Engineering, National Research Council, 1919-1921

Jury of Awards, St. Louis, 1904; Chairman, Board of Awards for Edison Medal, 1921

President, Board of Awards for John Fritz Medal, 1922-1923

Chairman, Secretary, and Member of the American Institute of Electrical Engineers Standards Committee, 1910-1930

Member, Boiler Code Committee, American Society of Mechanical Engineers

Founder and first Chairman, American Engineering Standards Committee, now American Standards Association, 1920

WAR PERIOD

Chairman, General Engineering Committee, Council of National Defense

Chairman, Welding Committee, Emergency Fleet Corporation

Co-Founder and Chairman, Division of Engineering, National Research Council

CONTRIBUTIONS

D-c machines: original formula for commutation reactance voltage, covering approximations in relation to number of segments spanned by brush and the arrangement of the conductors in the slot.

Induction motors: first to distinguish between the space-phase and time-phase significance of induction-motor vector diagrams.

Synchronous machines: first to distinguish space-phase and time-phase vector diagrams in the analysis of synchronous machines; first to present a rational method of computing the emf wave of an alternator, in terms of the field form and type of winding; designed the first alternator which would maintain a sine wave under all conditions of load and excitation; first to parallel accurately two alternators in the clutch connection of the same shaft; developed a complete method of design and calculation for single-phase self-starting synchronous motors.

Synchronous motors: first to apply the mmf space vector diagram to synchronous motors.

A-c commutator motors: developed a method of design for series a-c commutator motors.

Electrical machine design: originated a systematic analysis of electrical machinery included in "Design Schedules," *Harvard Engineering Journal.*

Research on electrical machinery: extensive research program at Harvard University and Massachusetts Institute of Technology on various subjects pertaining to electrical machinery. Some of the fields were on iron losses, belt leakage and reactance, pole face losses, and the characteristics of special machines. Special research on theory of oscillographs, electric hammers, induction heating, etc.

Welding field: regarded as a pioneer and authority in the welding field.

Induction heating: contributed basically to the field of induction heating. Cooperated in the development of high-frequency alternators and the auxiliary equipment involved.

Insulations and cable design: first to recognize internal corona in coil insulation; contributed to research of underground cable design and testing methods.

Special problems: in 1902 designed a small 350-cycle induction motor to run at 20,000 rpm; in 1903 conducted a comprehensive research on the Heyland Machine as generator and motor; in 1904 designed a d-c motor for the first successful direct drive of sugar centrifugals; in 1913 designed a sine wave alternator for cable testing; first to develop a simple, rational, and quantitative method of determining the relationship between the field form, the type of winding, and the resulting wave shape of alternators; in 1909 conducted an extensive research on pole face losses which superseded any previous formulas; in 1914 investigated the cause of failure of two 25,000-kw alternators for the Public Service Corporation of New Jersey; specialized in inductive heating and induction furnaces and designed some of the largest such furnaces in this country.

Specific contributions to Edward G. Budd Manufacturing Company: Ragsdale fundamental patent on "SHOTWELD" proc-

ess; welding recorder; Budd mechanical timer; welding transformer; feeders for welding transformers; automatic welding machines for Chevrolet chassis; Chevrolet rear axle housings; welding tips; independent heating, lighting, and air-conditioning equipment for rail cars; welding research; inductive heating; Eddy current brake; internal inductive heating patents; a-c electrical transmission for steam turbine locomotives; d-c locomotive transmission for gas turbine drive.

A PARTIAL BIBLIOGRAPHY

KEY TO ABBREVIATIONS

Proc. Am. Inst. Elec. Engrs. = Proceedings of the American Institute of Electrical Engineers

Trans. Am. Inst. Elec. Engrs. = Transactions of the American Institute of Electrical Engineers

1902

Alternator regulation. A series of articles published in the Harvard Engineering Journal.

1903

The Heyland machine as a motor and as a generator. Trans. Am. Inst. Elec. Engrs., 20:761-810.

1904

The leakage reactance of induction motors. Trans. International Electrical Congress, St. Louis, 1:706.

The induction motor. A series of articles published in the Harvard Engineering Journal beginning in June.

Circle diagram of repulsion motor. Trans. Am. Inst. Elec. Engrs., 21:215-28.

1905

Design of induction motors. Proc. Am. Inst. Elec. Engrs., 24:327-62.

Reactance E.M.F. in dynamo design. Electrical World and Engineer, 46:346-48.

1907

With W. K. Cabot and G. Irving, Jr. Fractional pitch windings for induction motors. Proc. Am. Inst. Elec. Engrs., 26:1245-63.

Polyphase power measurements. Paper presented at the A.A.A.S. in December 1906. Electrical World, 49:143-44.

1908

Voltage ratio in synchronous converters with special reference to the split-pole converter. Proc. Am. Inst. Elec. Engrs., 27:899-925.

The synchronous motor. A series of articles published in the Harvard Engineering Journal during 1908-1909.

1909

E.M.F. wave-shape in alternators. Proc. Am. Inst. Elec. Engrs., 28: 791-814.

With A. C. Lanier, C. C. Pope, and C. O. Schooley. Pole-face losses. Proc. Am. Inst. Elec. Engrs., 28:1063-86.

1913

Two chapters in: *Synchronous Motors and Converters,* by André Eugène Blondel. New York, McGraw-Hill Book Co., Inc.

1919

Cooperation. Retiring address as president of the A.I.E.E. Trans. Am. Inst. Elec. Engrs., 38:783-93.

1926

The welding of iron and steel. Paper presented at the A.I.S.I. in October. Yearbook of the American Iron and Steel Institute, pp. 305-75.

Dynamo design schedules. A skeleton of dynamo design procedure covering four fundamental types of electrical machinery. Published first in 1907, revised in 1926.

1931

The welding of pressure vessels with special reference to the X-ray examination of welded joints. Address before the American Boiler Manufacturers Association, May. Combustion, 3:16-21, 24.

1934

With J. C. Hodge and M. H. Mackusick. High frequency induction furnaces. Electrical Engineering, 53:194-205.