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ROSS GUNN

1897—1966

A Biographical Memoir by

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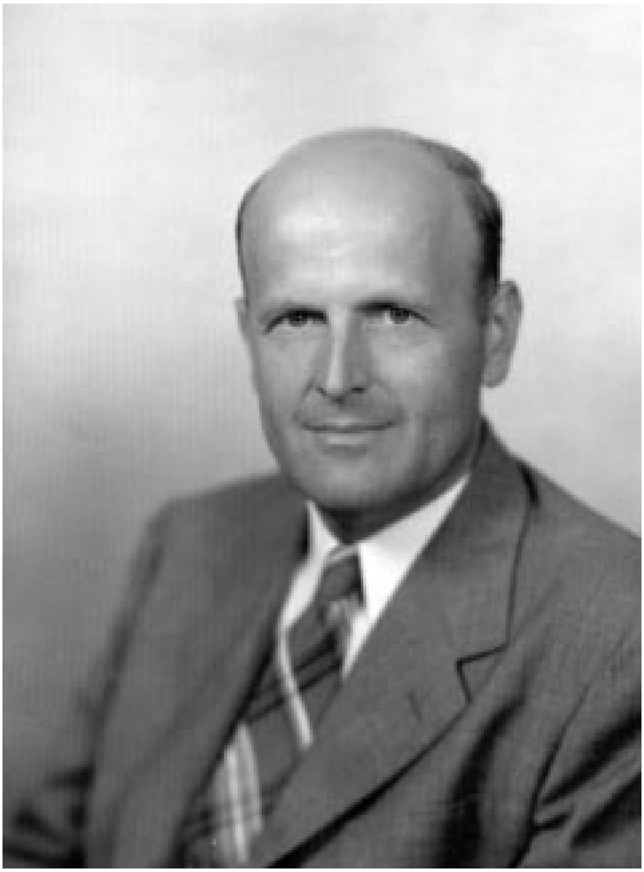

Ross Gunn

ROSS GUNN

May 12, 1897–October 15, 1966

BY PHILIP H. ABELSON

Ross Gunn was one of the most versatile physicists of the early and mid-twentieth century. He made significant contributions to knowledge in many fields of science and technology. He created novel instrumentation, much of which was designed to facilitate studies of natural phenomena such as thunderstorms. In the course of his career he obtained more than forty patents.

From 1927 to 1947 Gunn was a research physicist on the staff of the U.S. Naval Research Laboratory. In 1934 he was appointed technical adviser for the entire laboratory. In that role he interacted with important naval personnel. In March 1939 he wrote a memorandum to Admiral H. G. Bowen, chief of the Navy's Bureau of Ships, outlining the tremendous advantages that could be expected from the use of atomic energy in submarine propulsion.

In the latter years of World War II Gunn was simultaneously superintendent of the Mechanics and Electricity Division, superintendent of the Aircraft Electrical Division, and technical director of the Army-Navy Precipitation Static Project, as well as technical adviser to the naval administration. He also fostered development of the liquid thermal diffusion method for separation of uranium isotopes. This led to large-scale use of the process by the U.S. Army's Manhattan District at Oak Ridge, Tennessee.

In February 1947 Gunn became director of the Weather Bureau's Physical Research Division, where for ten years he conducted and supervised important research related to severe weather phenomena. Until his death in 1966, he remained active in research and consultation while a professor of physics at American University.

Ross Gunn was born in Cleveland, Ohio, on May 12, 1897. His forebears were of Scotch and English descent. Three of his ancestors were soldiers in the American Revolution; two served as officers directly under George Washington. His father Ross D. A. Gunn was a graduate of Western Reserve Medical College and a practicing physician. As undergraduates, both his father and mother (Lora A. Conner) attended Waynesburg College in Pennsylvania.

In 1923 Ross married Gladys J. Rowley, an alumna of Oberlin College. Over the next fifteen years four sons were born—Ross, Jr., Andrew Leigh, Charles, and Robert Burns. All have had successful professional careers. Ross Gunn, Jr., who holds a degree in electrical engineering and an M.B.A., is in business in California. Rev. Andrew Leigh Gunn attended Yale Divinity School and is a minister. Charles Gunn is an aeronautical engineer and at one time was director of the NASA shuttle program. He is now engaged in private enterprise. Robert Burns Gunn is currently professor of physiology and chairman of the Department of Physiology at the Emory University School of Medicine.

While in high school in Oberlin, Ohio, Gunn became interested in amateur radio (then called wireless telegraphy). Without help, he built a successful wireless receiving apparatus and qualified for a commercial wireless operator's license. He also built one of the first long-range amateur wireless stations in northern Ohio and carried on conversations with amateur stations in most regions of the United States. These early activities in radio are reminiscent of the youthful interests of other physicists, including Ernest O. Lawrence and Merle A. Tuve.

Ross entered Oberlin College in 1915, but after two years he transferred to the University of Michigan. With the entry of the United States into World War I he enlisted as a private in the Signal Corps and was later called to active duty. He received his B.S. degree in electrical engineering in 1920 and an M.S. degree in physics in 1921 from the University of Michigan.

In the interval from 1921 to 1923 Gunn spent a year and a half with the U.S. Air Service as a radio research engineer. As part of his duties he did pioneer work in developing a radio range aircraft navigation system. In the course of this work he made a number of the first cross-country instrument flights. While employed in the U.S. Air Service he also developed devices for radio control of pilotless airplanes (drones). The Navy later used this technology as the master control mechanism for fifty of its first pilotless aircraft.

The years from 1923 to 1927 were spent at Yale University, where Gunn held an appointment as instructor in engineering physics and where he received a Ph.D. degree in physics in 1926. One of his mentors at Yale was Professor Leigh Page, a theoretical physicist. A consequence was a good grounding in classical physics.

In his later career Gunn combined excellent capabilities in identification of important problems with skill in developing innovative instrumentation, a zest for experimental work, and aptitude for theoretical analysis of practical problems.

In 1927 Gunn accepted an offer from the Naval Research Laboratory to become a research physicist in the Radio Division. He intended to spend only a few years at the laboratory, but he remained there until 1947. In the pre-war years the civilian staff was small and the naval officer management was willing to encourage pioneering basic research related to radios, the new electronics, and instrumentation employing vacuum tubes. Gunn was skilled in these areas, and he interacted well with naval personnel. Within a year he was promoted to assistant superintendent of the Heat and Light Division. He was allowed to choose his own agenda. During the period 1929-33 Gunn published twenty-eight articles in the open literature. Most of the items were theoretical treatments of natural phenomena, such as terrestrial and solar magnetism, cosmic rays, and other astrophysical phenomena. Thirteen of the articles were published in *Physical Review*. The remainder appeared in other standard journals. During this highly productive period Gunn invented and was subsequently granted seventeen patents on useful instrumentation. One device was an induction-type electrometer that could produce an induced alternating voltage from a small free charge. The basic principle was incorporated in a large number of instruments, including the vibrating reed electrometer. In addition to these activities, Gunn conducted classified research relevant to naval problems.

In 1934 Gunn was appointed technical adviser for the entire Naval Research Laboratory. He became responsible for the quality of the technical program and its coordination with the needs of the naval service. He took this top administrative and scientific job with the understanding that he would be given skilled assistance and that he would be allowed to continue his own research on problems of interest to the Navy.

In 1938 Gunn invented and subsequently patented another instrument that was widely used—a portable device that amplified thermocouple electromotive forces. The instrument was useful in detecting infrared radiation emitted by enemy ships and aircraft.

During the World War II years Gunn was assigned many administrative duties in addition to his role as technical adviser to the naval administration. One of them was to act as technical director of the Army-Navy Precipitation Static Project. This was a successful effort to identify and alleviate interference produced on aircraft flying through ice-crystal clouds or snow. A group headquartered in Minneapolis conducted the major part of the investigation.

Immediately after the announcement of the discovery of uranium fission in early 1939, Ross Gunn became a keen observer of and participant in developments relevant to nuclear power. He was particularly interested in its possible application to propulsion of submarines. Conventional submarines were propelled by batteries, which in turn were charged by electricity supplied by generators coupled to diesel engines. These required air. While near the surface of the ocean, the submarines were vulnerable to detection and attack.

By mid-1940 it had become evident that the rare ^{235}U was fissionable and that a chain reaction creating nuclear power was likely to be achieved. Gunn learned that I was conducting experiments on uranium isotope separation and arranged to provide me with financial support. I was then an employee of the Carnegie Institution of Washington. I obtained my first tiny isotope separation using equipment manufactured by me, but housed at the National Bureau of Standards. The method involved liquid thermal diffusion of uranium hexafluoride (UF_6). The simple apparatus consisted mainly of three concentric tubes 12 feet long. The inner tube was heated by steam. A second tube was maintained at 65° C. The third tube served to contain the 65° C cooling water. The UF_6 occupied the space between the walls of the inner and middle tubes. Runs on this column were made in April 1941, when a measurable isotope separation was obtained.

When Gunn learned that I had achieved a small separation of uranium isotopes, he invited me to join the staff of the Naval Research Laboratory, where enhanced supplies of high-pressure steam could be made available. In June 1941 the move was made. A series of experiments was conducted to determine the optimum spacing between the hot and cool walls. In June 1942 a column 36 feet long heated by 100 psi of steam produced an isotope separation factor of 1.11. This success led to an expanded effort that included authorization to build and operate fourteen columns 48 feet long. It also led to the procurement of a propane-fired boiler capable of delivering 1,000 lb/in^2 of steam. For a time, the facility at the Naval Research Laboratory was the world's most successful separator of uranium isotopes.

Ross Gunn, who was a member of the federal government's S-1 uranium committee, communicated results of the isotope experiments to committee chairman Lyman J. Briggs in August 1942. This led in October 1942 to a visit to the Naval Research Laboratory by General Leslie R. Groves and Admiral W. R. Purnell. Later, in January 1943, a special committee assembled by the Manhattan District inspected the installation. The committee was impressed by the simplicity of the equipment and commented favorably.

A Naval Research Laboratory report submitted to the Bureau of Ships by Gunn in January 1943 pointed to the advantages of using enriched uranium in nuclear reactors. It would be a necessary step in creating a nuclear-powered submarine. The report also stated, "A liquid thermal diffusion plant costing one to two million dollars could provide the necessary separated isotopes."

During the next six months, improvements were made in the construction of the separation columns. At the same time, the pilot plant produced 236 pounds of UF_6 possessing isotope separation. The quantity and the separation were greater than had been obtained by the gaseous diffusion method at that time.

Gunn decided that an expansion of production capabilities of the liquid thermal diffusion method was warranted. Doing so would provide an alternative if the Manhattan District's magnetic and gaseous diffusion methods failed. A survey of naval establishments showed that large-scale sources of high-pressure steam could be made available at the Naval Boiler and Turbine Laboratory at the Philadelphia naval base. Authorization to build a 306-unit plant at Philadelphia was obtained on November 27, 1943. Rear Admiral Earle Mills, assistant chief of the Bureau of Ships, signed the project order.

In June 1944 the Philadelphia plant was approaching completion. J. Robert Oppenheimer learned of the progress and recognized that a supply of partially separated uranium would increase the production of an electromagnetic plant at Oak Ridge. He communicated with General Groves, who sent a reviewing committee to the Philadelphia plant. Its report was favorable and led to the decision to build a 2,142-column plant at Oak Ridge. Construction there was rapid. The $20-million facility achieved production that shortened the duration of World War II by eight days.

Secretary of the Navy James Forrestal presented the Navy Distinguished Civilian Service Award to Ross Gunn on September 4, 1945. The citation included:

> For exceptionally distinguished service to the United States Navy in the field of scientific research and in particular by reason of his outstanding contribution to the development of the atomic bomb . . . For his untiring devotion to this most urgent project, Dr. Gunn has distinguished himself in a manner richly deserving of the Navy's highest civilian award.

Immediately after the end of the war Gunn returned to the concept of the nuclear submarine. Methods of detecting diesel-powered submarines had advanced greatly. In the latter part of World War II large numbers of German submarines had been destroyed. I was tasked with becoming familiar with the current state of nuclear reactors, particularly those using enriched uranium. I was provided with access to experimental programs at Oak Ridge and Argonne, and I participated in criticality experiments of enriched uranium assemblages.

Gunn also took part in obtaining blueprints of the most advanced German submarine. Analysis showed that the energy system of the submarine could be replaced by a shielded nuclear reactor. In September 1946 a report on the feasibility of a nuclear submarine was submitted to the Bureau of Ships. Later, Admiral Hyman Rickover directed a highly successful development and construction of nuclear submarines. However, some part of the credit for nuclear submarines belongs to Ross Gunn.

In the late autumn of 1946 Gunn decided he would not accept additional naval administration duties. Rather, he would return to more science-oriented activities. In February 1947 he transferred to the Weather Bureau to organize and direct a fundamental study of the basic physics of weather. A core objective was to investigate the processes responsible for precipitation under various physical conditions. His first task as director of the Weather Bureau's Physical Research Division was to organize a program to study the practicality of producing rain by cloud seeding. Results showed that while sometimes rain was produced, it was insufficient to be of much economic value. Subsequent events showed this early conclusion to be correct.

Physicists who are inclined to observe and study natural phenomena have been presented with great opportunities and puzzles. Among these are solar-terrestrial climatic effects, possible human-induced global warming, and violent weather phenomena. As early as 1935 Gunn became sufficiently interested in thunderstorms to begin studies on them. A paper titled "The Electricity of Rain and Thunderstorms" was published in *Terrestrial Magnetism and Atmospheric Electricity.* In 1944, after being named technical director of the Army-Navy Precipitation Static Project, Gunn participated actively in choosing instrumentation for it and in devising research and instrumentation aspects. Later he analyzed many of the experimental results. In the course of the program, airplanes flew through twenty-five thunderstorms collecting valuable data. These measurements provided what was then and later the best available cross section of thunderstorm electrification data. The airplanes were equipped with induction-type electric field meters placed on both the top and bottom of the main cabin. An apparatus capable of measuring the electric charge on snow and raindrops was installed under one wing. Simultaneous measurements could be made on the electric fields and on the charges on drops.

Repeated flights through active thunderstorms showed that the electric fields at levels close to ground were of the order of 1 to 10 volts/cm. These fields generally increased to a maximum in the vicinity of the freezing level. At this point the electric fields frequently exceeded 1,000 volts/cm. The aircraft encountered both negative and positive fields of 2,000 volts/cm and more. The charges on snow and raindrops were largest when the electric fields were high. The potential differences between the top and bottom of a thundercloud were frequently greater than 10^8 volts.

In 1947, soon after Gunn joined the U.S. Weather Service, he began to devise experiments and new equipment aimed at obtaining better knowledge of the basic physics of weather phenomena. His flair for the development of new equipment was repeatedly evident. An early example was an unprecedentedly huge cloud chamber. A mining shaft in Arizona 700 feet long and 7 feet square was sealed and provided with means to humidify and compress the air within it. When the pressure was suddenly released a dense cloud formed throughout the chamber. If water drops of known size were released at the top of the shaft their growth as they passed through the cloud could be measured.

In another set of experiments performed with different equipment the terminal velocity of various sizes of water drops was determined. The extensive data obtained from these studies were a unique contribution. The data continue to be widely used and quoted.

From the instrument development efforts emerged electric field meters capable of operating continuously in very heavy rain, whether on the ground or on aircraft. Instruments were also created to determine the sign and magnitude of free charges carried on falling rain. About these and other activities aimed at developing instrumentation Gunn could state, "As a direct result of efforts to develop new and better instruments, we have the largest store of coherent measurements yet made in the field of atmospheric electricity."

As a fellow of the Institute of Radio Engineers, Gunn was invited to write an article that appeared in 1957 describing recent developments in an important field of his choosing. He chose to present some of the knowledge that had been created about thunderstorms. I have selected a few items from the article to paraphrase and summarize:

- Cosmic rays and radioactivity produce at heights just above ground level about 10 positive and 10 negative ions/sec. At an altitude of 15 km, the rate of production is about 45 pairs/sec.
- In a cloud that is not yielding rain the net overall charge is zero. However, droplets in the cloud become charged. About half are positive and about half are negative.
- Charges on raindrops may become enhanced when small

drops join together to make large drops. When there is turbulent motion in the cloud, the relative mobility of plus and minus ions results in differential charging and in separation of charged droplets. The electrification observed in thunderstorms implies a gross separation of free electrical charges with a consequent expenditure of large amounts of energy.

- An important index of thunderstorm activity is the electric field measured both at ground level and inside an active cloud high above. In fair weather, the surface field intensity is negative and of the order of -1.5 volts/cm. In a typical thunderstorm the electric field at the ground may increase to +/- 100 volts/cm and more. The field may be negative part of the time, but mostly it is positive. The field changes instantaneously during and immediately after a lightning strike and then recovers. Often the direction of the field overshoots during the strike.
- The typical summer thunderstorm is about 20 km in diameter. The cloud mass itself may be somewhat larger. It commonly extends vertically about 12 km, but occasionally can extend to 15 km.
- Normal lightning activity is not observed in clear air except in the vicinity of falling precipitation. The principal electrical effects accompanying a thunderstorm are closely related to the production and fall of precipitation, but the connection of lightning and precipitation is not a direct one.

From 1947 until his death in 1966 Gunn devoted most of his efforts to the study of atmospheric phenomena. He created improved measuring equipment on which he was granted about thirty patents. He directed research while also conducting measurements. A substantial part of his effort was devoted to theoretical analysis of results obtained by him and others. He also published about forty articles in the scientific literature. He was the sole author on most of them.

After he left the Weather Bureau in 1957 Gunn's rate of publishing diminished. Much of his time was spent as a consultant. However, in the last four years of his life he returned to active experimental work and the development of instrumentation. The core of his efforts related to aspects of the physical phenomena occurring in thunderstorms. His professional office was located at American University, where he was a research professor of physics. One of his last publications was an extensive invited article in *Science*, which described a new instrument for studying effects of collisions between simulated raindrops.

In his approach to research, Gunn followed a procedure that many of the most successful scientists follow. He identified an important phenomenon that involved potentially measurable reproducible effects. He devised or procured instrumentation that would measure the effects more reliably than they had been previously. He analyzed the data using tools of a classical theoretical physicist but with the attitude of a practicing engineer. Others have followed and will follow in his footsteps. Some of his data and analyses will be improved on, but in many instances it will be noted that he was the first explorer to view the new frontier.

After his death an issue of the *Monthly Weather Review,* published by the U.S. Department of Commerce, was assembled as a memorial to Ross Gunn. It contained twenty-three articles, most of which dealt with violent weather phenomena. An exception was a biographical sketch portraying some of Gunn's character traits. Prepared by F. W. Reichelderfer, a member of the National Academy of Sciences, the article was titled, "Ross Gunn, the Scientist and the Individual." Reichelderfer chose to quote a portion of a talk Gunn had given in 1938 in which he described the ideal research physicist. Reichelderfer states that the words quoted reflected the standards set by Gunn as a scientist:

> The scientist should be distinguished by intelligence and firm grounding in the fundamentals of physics, chemistry, and engineering. He should be especially keen in estimating situations and reaching sound decisions. His judgment and perspective should be such that he can give his talents systematic direction. He should be an original thinker . . . exceptional in his ability to plan, think, and do things without being told. He should have the courage of his convictions, yet not be blinded by them. He should *constantly seek the truth.* He should be especially successful in working harmoniously with others toward a common end.

In my dealings with Ross Gunn I noted that in a situation where he was certain of the facts, he did not avoid conflict, and he was resourceful when in a fight. Reichelderfer perceived a different side of Gunn's character. He stated:

> Any man whose work comes to public attention and who holds to his beliefs when the facts support them encounters opponents as well as supporters, especially when his work may incidentally affect the ambitions of others. So Gunn had his critics—this is rather well known. But he has strong support from associates who believe that most of the criticism directed at him was a result of misunderstanding, sometimes misrepresentation or ignorance of what he actually thought and did. Gunn's nature did not make him inclined to waste time in "explaining" to critics. He hoped the facts would speak for themselves and in such matters he preferred to remain silent.

During his life, in whatever role he found himself, Ross Gunn gave the best he could. As a result, his existence made the kind of difference to this world that only a few achieve.

SELECTED BIBLIOGRAPHY

1930

On the anomalous rotation of the sun. *Phys. Rev.* 35:635-42.

A new frequency stabilized oscillator system. *Proc. Inst. Radio Eng.* 18:1560-74.

1932

A mechanically resonant transformer. *Proc. Inst. Radio Eng.* 20:516-619.

Principles of a new portable electrometer. *Phys. Rev.* 40:307-12.

On the evolutionary origin of the solar system. *J. Franklin Inst.* 213:639-59.

1935

The electricity of rain and thunderstorms. *Terrestr. Magnet. Atmos. Electr.* 40:79-106.

1938

Some experiments on the amplification of thermocouple electromotive forces. *Rev. Sci. Instrum.* 9:267-69.

1946

With R. G. Stimmel, E. H. Rogers, and F. E. Waterfall. Electrification of aircraft flying in precipitation areas. *Proc. Inst. Radio Eng.* 34:167-77.

With J. P. Parker. The high-voltage characteristics of aircraft in flight. *Proc. Inst. Radio Eng.* 34:241-47.

1947

The electrical charge on precipitation at various altitudes and its relation to thunderstorms. *Phys. Rev.* 71:181-86.

1948

Electric field intensity inside of natural clouds. *J. Appl. Phys.* 19:481-84.

1949

The free electrical charge on thunderstorm rain and its relation to droplet size. *J. Geophys. Res.* 54:57-63.

With G. D. Kinzer. Terminal velocity of fall of water droplets in stagnant air. *J. Meteorol.* 6:243-48.

1950

The free electrical charge on precipitation inside an active thunderstorm. *J. Geophys. Res.* 55:171-78.

1952

A vertical shaft for the production of thick artificial clouds and the study of precipitation mechanics. *J. Appl. Phys.* 23:1-5.

1954

Electric field meters. *Rev. Sci. Instrum.* 25:432-37.

Diffusion charging of atmospheric droplets by ions and the resulting combination coefficients. *J. Meteorol.* 11:339-47.

1955

The statistical electrification of aerosols by ionic diffusion. *J. Colloid Sci.* 10:107-19.

Droplet electrification processes and coagulation in stable and unstable clouds. *J. Meteorol.* 12:511.

Raindrop electrification by the association of randomly charged cloud droplets. *J. Meteorol.* 12:562-68.

1957

The electrification of precipitation and thunderstorms. *Proc. Inst. Radio Eng.* 45:1331-58.

1964

The secular increase in the world-wide fine particle pollution. *J. Atmos. Sci.* 21: 168-81.

1965

Collision characteristics of freely falling water drops. *Science* 150:695-701.

Thunderstorm electrification and raindrop collisions and disjection in an electric field. *Science* 150:888-89.

1966

Thunderstorm electrification of hail and graupel by polar dribble. *Science* 151:686-87.