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JOHN RANDOLPH WINCKLER
1916–2001

A Biographical Memoir by

KINSEY A. ANDERSON

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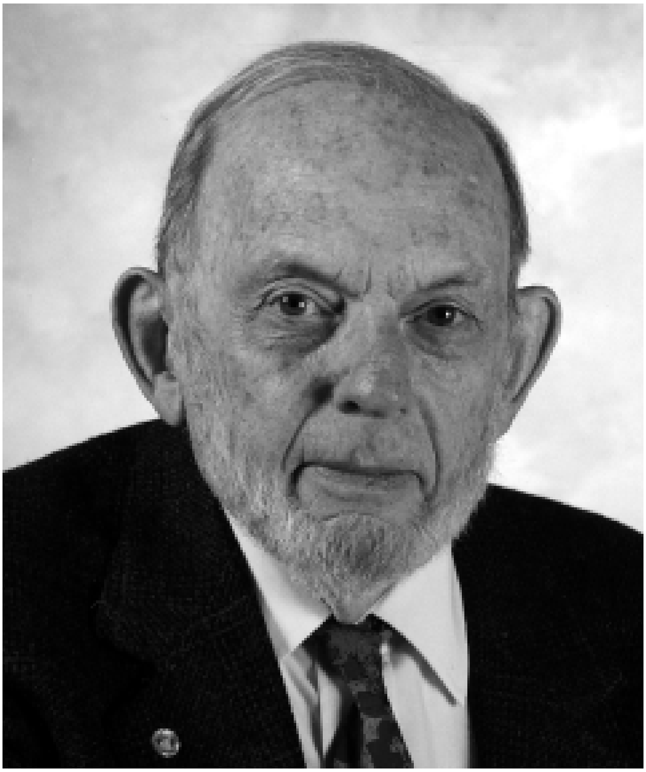

John R. Winckler

JOHN RANDOLPH WINCKLER

October 27, 1916–February 6, 2001

BY KINSEY A. ANDERSON

JOHN RANDOLPH WINCKLER was a gifted experimental physicist who made major discoveries in solar, magnetospheric, auroral, and atmospheric physics. He designed and built experimental apparatus for flight on balloons, sounding rockets, and Earth-orbiting spacecraft. Some instruments were exquisite in their simplicity, others highly complex. However, all fit the needs of Winckler's scientific objectives. Early in his research career he ingeniously adapted systems used by the U.S. Navy to detect submarines during World War II to retrieve scientific data from high-altitude research balloons. His first major scientific discovery was to show that electrons with energy in the range of tens to hundreds of kiloelectron volts accompanied bright, active aurora. A few months later with L. E. Peterson he observed and measured an intense and short-lived burst of photons in the energy range of tens to hundreds of kiloelectron volts. The burst was coincident with a bright and active solar flare. This discovery added a new dimension to the study of high-energy particle phenomena occurring on the Sun.

He made many investigations of the geomagnetically trapped energetic particles including "active" experiments.[1] This work required a major technical effort in order to develop instrumentation carried on rockets that could deliver short but intense packets of electrons onto geomagnetic field lines that extended out to great distances from the Earth. The results confirmed and extended several theoretical predictions of charged particle trapping in Earth's magnetic field.

In 1986 John Winckler became professor emeritus and gave up all but a very small amount of extramural research funding. Combining aesthetic inclinations with his scientific insights, he turned to studies of the night sky. Spending many nights at an observatory away from city lights, he was able to demonstrate with fast imaging techniques that some lightning strokes were directed from cloud tops to the ionosphere. His quantitative, high time-resolution measurements stimulated much experimental and theoretical activity among atmospheric research groups across the United States.

THE EARLY YEARS

John Randolph Winckler was born on October 27, 1916, in North Plainfield, New Jersey. Important early influences during his childhood and youth came from his father, an accomplished violinist and amateur photographer. A grandfather was skilled in metal and woodworking. The family, including the young John Winckler, made many outings in surrounding hills and along the streams of eastern New Jersey. These were occasions to observe and study the plant and animal life, and for the grandfather to make paintings and drawings of plants and landscapes. One night during Winckler's youth his father pointed skyward to a display of the aurora borealis. During his professional career Winckler would contribute to the understanding of physical processes that produce the visual auroral displays. The aesthetic appreciation for the natural world Winckler developed in those early years would later become unified with his scientific interests.

As a schoolboy he became interested in the new medium of radio and learned to build AM receivers. To better receive distant radio broadcasts he strung an antenna from the attic of the house to a tall tree. While in high school he built a radio for the family's living room. Winckler's wife, Louise, recalls having seen it. She remembers it as a large object occupying a considerable amount of floor space. During these school years Winckler developed his interest in photography and set up a darkroom to develop and print photographs in the basement of the family home.

John Winckler graduated from high school in 1933 during the Great Depression. His father retained employment as an accountant in a bank during those years. The bank was one of the few in the area that did not close its doors. According to Winckler's children, there had not been a tradition of higher education in his family so Winckler did not immediately go on to college or university although it was financially possible to do so. He then worked at a variety of jobs in and around North Plainfield from 1933 to 1936. According to members of his family, one of these jobs was at a Bell Telephone facility, where his talent and experience with AM radio could be utilized. During these post-high-school years he continued his interest in music and sang at weddings and other occasions. He gave some thought to having a career as a musician. Years later his great baritone voice sometimes would be heard throughout the physics building at the University of Minnesota. While pursuing his musical interests he met concert pianist Louise McDowell. They married in 1943 and raised a family of four daughters and one son.

In 1937, as the United States economy began to improve, Winckler secured employment at a Johns Manville research and development facility. He worked there until 1942. Early in his Johns Manville employment Winckler's intelligence and ingenuity were recognized by one of the engineers who suggested that Winckler obtain higher education. Winckler enrolled in Rutgers University, receiving a bachelor of science degree in 1942, nine years after graduating from high school. During the Rutgers years Winckler continued on at Johns Manville. The work there resulted in his first publication in a scientific journal. It bears the title "Spherical Furnace Calorimeter for Direct Measurement of Specific Heat and Thermal Conductivity." The article was solely authored by Winckler, and its publication appeared about one year after his graduation from Rutgers.

He was then admitted to Princeton University's graduate study program. During the years 1943 and 1944, while studying and carrying out research at Princeton, Winckler held a position with the U.S. Office of Research and Development. Family members believe that the U.S. military, rather than drafting Winckler into active service, preferred to have him continue his studies of supersonic air flow at a time when development of supersonic aircraft was beginning. The title of his Ph.D. thesis was "Interferometric Study of an Axially Symmetric Air Jet"; his advisor was R. Ladenberg. The results of this research were published in *Physical Review* and in *Review of Scientific Instruments*. After receiving his doctor of philosophy degree from Princeton in 1946 he was appointed instructor in physics.

GALACTIC COSMIC RAY STUDIES

After World War II scientists who had worked on radar, nuclear weapons, and other projects having a technical or scientific basis were returning to universities and research laboratories. Physics department planners were seeking areas of basic research to explore using the new techniques and instrumentation developed during wartime. Older areas of research that could be revitalized by the new knowledge and techniques also received attention. One such area of interest was the nature of galactic cosmic rays. At this time little was known about the fundamental character of this physical phenomenon.

Shortly after the end of World War II Princeton University began an experimental cosmic ray program in its Palmer Laboratory. There John Winckler designed and built a system for balloon flight to measure the cosmic ray particle intensity as a function of geomagnetic latitude and its dependence on azimuthal and zenith arrival angles. He took much care to eliminate spurious effects that otherwise could prevent an accurate determination of the cosmic ray intensity. His cosmic ray "telescope" consisted of three trays, each containing 10 Geiger-Mueller tubes. A three-fold coincidence was registered when one or more tubes in each of the three trays gave an output within the resolving time of the electronic circuits. The presence of a center tray reduced the number of spurious coincidence counts, and other measures were taken to insure accuracy of the results. The geometric factor was about 22 cm^2 steradians, quite large for that time. Winckler credited H. V. Neher of the California Institute of Technology for recognizing the value of a counter telescope having the largest possible geometric factor.

Winckler had set up a facility to manufacture and test the Geiger-Mueller tubes for 21 flight systems plus a number of spare tubes. The number of tubes including spares would have been approximately 800.[2] To retrieve data from the flight instruments launched from shipboard, Winckler had ingeniously adapted surplus U.S. Navy equipment originally designed to detect German submarines operating off the coast of the eastern United States. His apparatus was the most complex cosmic ray flight system designed and was successfully flown on balloons up to that time (1947-48).

About 21 flight units were taken aboard the U.S. Navy's seaplane tender, the USS *Norton Sound*. The ship left Port Hueneme, California, in early July and sailed generally southwest to Jarvis Island, near the equator and south of Honolulu, covering the range of geomagnetic latitude 40° to 0°. Only one of the 17 flight units that were launched failed to provide the desired scientific results, a remarkable record of success for those early days of high-altitude experimentation. Three identical cosmic ray telescopes were operated continuously onboard the ship to monitor the sea-level cosmic ray intensity. Winckler credited the Princeton Naval Observatory and professors J. A. Wheeler and G. T. Reynolds for "major support of the effort." In his comprehensive history of cosmic ray research, unpublished at the time of this writing, John E. Naugle gives an assessment of Winckler's latitude survey: "Winckler's experiment is of historical interest because it demonstrated the best data that could be obtained using only Geiger counters and showed the need for more sophisticated instruments for future research on the cosmic radiation."

At this time scientists at several other universities in the United States were also attracted to the problem of galactic cosmic rays as a promising research area. One of these was the University of Minnesota. Winckler accepted their offer of an assistant professorship in the Physics Department, arriving there late in 1949. He continued his program to understand the discrepancies between his measurements and the predictions of geomagnetic theory. One likely source of error was that cosmic ray protons and heavy ions made nuclear interactions in the atmosphere, producing secondary particles. Some of these secondaries would move upward and leave the atmosphere—the "splash albedo." A fraction of these particles would be deflected by the geomagnetic field and re-enter the atmosphere. Measurement of this secondary component would improve quantitative knowledge of the primary cosmic ray number-energy spectrum. He and his graduate students pursued this line of research for a time, using Cerenkov detectors flown on balloons for the first time in order to determine the direction of motion of fast particles at altitudes of about 30 km. This provided him with the flux of upward moving fast particles that would have been counted but not discriminated against by counter telescopes using Geiger-Mueller tubes. By 1950 other groups were combining Cerenkov and scintillation detectors and finding the combination to be a powerful technique for determining the atomic number and velocity of energetic particles arriving at Earth. Moreover, solid-state detectors soon would be introduced. The cosmic ray problem was beginning to be seen in the broader framework of high-energy astrophysics.

THE INTERNATIONAL GEOPHYSICAL YEAR, 1957-1958

The cosmic ray group at the University of Minnesota also included Professor Edward P. Ney and Phyllis Freier. These two scientists were codiscoverers, along with H. Bradt and B. Peters of the University of Rochester, of nuclei having atomic number equal to or greater than 2 in the galactic cosmic rays. With Winckler's arrival the University of Minnesota group was ready for new research initiatives.

From 1955 scientific bodies throughout the world were planning the International Geophysical Year and funding for research projects was becoming available. Freier, Ney, and Winckler developed a proposal to monitor the galactic cosmic radiation intensity during the 18-month period that began on July 1, 1957. Their idea was to keep cosmic ray detectors at an altitude of about 30 km for a substantial fraction of this interval using constant altitude polyethylene (Skyhook) balloons. Each balloon would remain at high altitude from several hours to an entire day. They proposed a payload consisting of three traditional cosmic ray instruments: a Neher-type integrating ionization chamber, a single Geiger-Mueller tube, and a small stack of nuclear emulsions. The latter would record the tracks of heavy cosmic ray nuclei with atomic number 2 and greater. The payload would also include an atmospheric pressure measuring device to obtain the amount of residual atmosphere and a camera to record the ground track of the balloon. The IGY committee accepted the Freier, Ney, and Winckler proposal. The Minnesota project was one of the larger scientific enterprises accomplished during the IGY.

Winckler oversaw the design, fabrication, testing, and calibration of the ion chambers and Geiger-Mueller tubes. He devised the data recording and telemetry systems carried on each balloon and played a major role in organizing the required logistic support for the project. He chose the times when balloon launches would be made and supervised the launch operations for most of the flights. A total of 83 such flights were made during the IGY period. Most launches were made from the Minneapolis, Minnesota area, others from locations in the Midwestern United States, Texas, Alaska, Guam, and Cuba.

Winckler thought it appropriate to launch a balloon carrying the Minnesota standard IGY payload on the very first day of the IGY. The instrument package left Winckler's hands at 0107 GMT. The balloon reached its maximum altitude and floated there collecting data for 20 hours. During the night a brilliant auroral display appeared over Minneapolis. The Geiger counter and the ionization chamber registered large and rapidly fluctuating fluxes of X rays. Winckler and colleagues interpreted the X rays as *bremsstrahlung* produced by electrons with energies ranging from 10 to 100 kiloelectron-volt incident on the atmosphere above the balloon. This result was unexpected, although in 1955 James Van Allen's rockoon group had detected "soft" electrons, but the energy of those electrons was not sufficiently high to produce X rays having tens to hundreds of kV energy observed over Minneapolis on July 1, 1957. Van Allen's discovery of geomagnetically trapped energetic particles was still several months in the future and Gold's general concept of the magnetosphere arrived in 1959. In retrospect Winckler's balloon observations can be seen as one of the earliest observed manifestations of Earth's magnetospheric energetic particle dynamics.

In 1959 Peterson and Winckler published a paper describing a burst of photons in the energy range 200 to 500 kiloelectron volts. It lasted about 20 seconds and was coincident with a bright solar flare. At this time it was known that following great solar flares, nucleons having energies of tens of millions of electron volts to as much as a billion electron volts occasionally appeared in interplanetary space. The result of Peterson and Winckler added a new dimension to solar high-energy particle phenomena.

The intensive coverage of the IGY flights led to an unexpected finding not related to solar phenomena. During two flights in 1958 launched from Minneapolis the detectors responded to "layers of radioactivity observed near the tropopause at Minneapolis, Minnesota." Working with Professor Homer Mantis, a professor of meteorology also at the University of Minnesota, upper-air trajectories were constructed showing that the "radioactivity was produced by nuclear bomb debris about one week old."[3] The air masses could be traced back to sites where Soviet nuclear explosive devices were known to have been detonated.

Winckler made many important contributions to knowledge and understanding of energetic solar nucleonic particles over the years 1959 through 1967. Using his talent and experience in design and construction of instruments that could operate unattended under severe environmental conditions, he provided many instruments for NASA spacecraft beginning with early NASA scientific missions. He contributed to the exploration of the geomagnetically trapped particle populations beginning in 1959 and continued those studies through 1980. Of particular importance were the studies he and colleagues made from data taken on geostationary satellites during periods when they were located above the night side of Earth over the period 1968 to 1980.

With coauthors he published several examples of solar high-energy photon emissions associated with solar flares following the first observed energetic photon burst made with Peterson in 1959. Of particular interest was the observation of a 16-second periodicity in the emission of solar X rays and solar microwave emission (with Parks).

Largely as a result of his discoveries during the International Geophysical Year, John Winckler became well known to researchers in European laboratories. He was invited to the solar physics branch of the Observatoire de Paris on several occasions and to the Centre d'Etude Spatiale de Rayonnement in Toulouse, France. He was invited to the Soviet Union on several occasions to present papers at the Leningrad Seminars, and he visited laboratories in and around Moscow at their invitation.

CONTRIBUTIONS TO THE TECHNOLOGY OF HIGH-ALTITUDE RESEARCH BALLOONS

After the Second World War large-volume balloons (~3000 m^3 and larger) were fabricated from thin (0.025 to 0.007 mm) polyethylene film. The basic design of these balloons was due to Jean Picard. The General Mills Corporation was among the first to fabricate these aerostats. Cosmic ray researchers were quick to make use of the polyethylene balloon to carry payloads having mass of tens and even hundreds or more kilograms to altitudes of about 30 km, where they would remain at a more or less constant altitude for 10 or more hours. Because of catastrophic failures resulting in the loss of scientific payloads and in property damage, an activity was initiated at the University of Minnesota's Department of Physics to improve performance of high-altitude balloons. The effort was led by professors Charles Critchfield, Edward Ney, and John Winckler. The project was supported by the U.S. Air Force, Army, and Navy, and its activities were classified during the years 1951-56. (All project documents were declassified in 1958.) The interest to the U.S. military in high-altitude, constant-level balloons was to place down-looking cameras in the balloon payloads, launch the balloons in Europe, and let the high-altitude balloons drift across the Soviet Union. The cameras would then be retrieved in "friendly" lands or waters. When U-2 aircraft became available, the University of Minnesota balloon project was swiftly cancelled.

The aim of the project at the University of Minnesota was to put all aspects of high-altitude balloon flight on a sound scientific and engineering basis. It would be necessary to understand the thermodynamics of balloon flight during both day and night and to develop better launch techniques, especially for heavy payloads. A major cause of balloon failure was thought to be large, circumferential tensions in the balloon film. Charles Critchfield and graduate student Leland Bohl calculated a balloon shape that would greatly reduce these tensions. Testing the design required full inflation of the balloons with an air-helium mixture. The test program was carried out in a large hangar in North Carolina used in World War II to house and maintain the blimps patrolling the eastern Atlantic seaboard for German submarines. At Winckler's request one of his graduate students designed and built a tensiometer to measure stresses in a biaxially stressed film. The student then carried out the circumferential and tangential measurements from the bottom of the balloon to its top and around several circles of latitude. Winckler shared responsibility for the flight testing of balloon shape designs with Professor Edward P. Ney. On a handwritten note found in his papers Winckler states that over his career he had full or shared responsibility for "more than 500 launches." His records show that he made approximately 150 balloon flights carrying purely scientific payloads. The inference is that Winckler and Ney conducted about 350 balloon launches under the technology development program over the years 1951 to 1956.

In addition to the large polyethylene balloons the project had designed a smaller balloon of Mylar film called the Tetroon. It was used for carrying small payloads to measure atmospheric parameters such as temperature and intensity of infrared radiation. Having trained the launch crews, Winckler or Ney did not have to personally supervise all launches, particularly the smaller balloons. Winckler also took on a major responsibility for the design and development of the instrumentation carried on all balloon flights—he was throughout his career an ingenious designer of electronic and mechanical devices. But his underlying interest was always to look more deeply into the workings of the natural world.

EXPLORING THE MAGNETOSPHERE WITH ARTIFICIAL ELECTRON BEAMS: THE ECHO PROJECT[4]

In the late 1960s John Winckler began a program of rocket experiments he called the "electron echo series." The initial aim was to verify the theory of electron motions in the Earth's magnetosphere, as Winckler did not entirely trust theoretical calculations that had never been tested against experiment. The basic idea was to fire a beam of electrons from a rocket above the atmosphere so that it would be reflected in the Southern Hemisphere and return to the rocket. The electron drift theory, largely due to Hannes Alfvén, predicted that the electrons would return to a point east of the injection point by an amount depending on the electron energy and on the electric and magnetic fields in the magnetosphere. Each electron echo flight raised new issues, and the next flight was planned to solve them.

The first experiment to fire an electron beam from a rocket had been carried out by Wilmot Hess at the NASA Goddard Space Flight Center. Hess's objective was to provide an accurately known injection to calibrate the auroral luminosity that it would produce. Winckler's first electron echo experiment, launched from Wallops Island, Virginia, on August 13, 1970, was successful, and echoes (electron reflections) were detected. In all subsequent experiments electrons were reflected in the Southern Hemisphere by convergence of the Earth's magnetic field, but from Wallops Island they were backscattered by the atmosphere, as the reflection point lies within the atmosphere.

In the next experiment Winckler turned to exploring the Earth's magnetic field in the vicinity of the auroral zone, which was thought to occur on the boundary between the "open" field lines connected to the interplanetary magnetic field and closed field lines that return to Earth. Electron Echo II was launched from Fort Churchill on Hudson Bay, Canada, on September 25, 1972. No echoes were detected, indicating that those field lines there were "open." All five subsequent experiments were launched from the Poker Flat Research Range, near Fairbanks, Alaska, with the overall intention of exploring the Earth's magnetic field and comparing the data with various models. Poker Flat is magnetically south of Ft. Churchill and the field lines there are "closed." In Echo 7 Winckler and Nemzek showed that the experiment also could measure electric fields, even electric fields parallel to the magnetic field, a very challenging experimental problem. Winckler also found that the ionospheric plasma was considerably heated by plasma instabilities produced by the electron beams. The later Echo experiments carried wave and plasma oscillation analyzers in their payloads.

Winckler's successful injection of electron beams from a rocket led other groups to start their own programs. Many of these experiments had little to do with reflecting an electron beam from the southern conjugate point but were trying to understand the heating of the local plasma and the generation of plasma waves and radiation. Such waves and radiation had been observed from Echo I, and the mechanisms involved are still not completely understood.

The Echo project was a major undertaking for a relatively small research group working within a university academic department. The machine and electronics shops, though not extensive, had highly skilled personnel. They contributed greatly to the success of the project, but equally important was the small group of graduate students who fully participated in the construction and conduct of the experiments and the data interpretation.

CLOUD-TOP-TO-IONOSPHERE LIGHTNING

In 1986 John Winckler became professor emeritus and ceased working on large NASA research projects. He continued his interest in the aurora and made casual auroral observations from backyard and lakeside, but often went to the O'Brien observatory operated by the University of Minnesota at a relatively dark site northeast of the twin cities of

Minneapolis and St. Paul. There he fashioned a simple light bucket consisting of an aluminum tube with a photomultiplier tube placed at its bottom. Pointed toward the dark sky the photometer recorded rapid flashes of light. Pursuing this result, Winckler arranged three such light buckets off the zenith with their axes 120° apart. Making use of the polarization of the light flashes due to Rayleigh scattering, he was able to determine the direction from which the light flashes were coming. He concluded that many of the flashes were due to lightning strokes from thunderstorms in the general direction of Florida.

Winckler then sought to image night-sky light flashes at high time and spatial resolution. He had a high-performance charge coupled device television camera remaining from the Echo project, but it was in need of renovation that would cost $7,000. He had a small amount of funds remaining from his NASA project, and the chairman of the University of Minnesota Physics Department provided additional funds for repair of the camera. With its repair Winckler began to make images of the night sky. During the night of July 5-6, 1989, he pointed the camera toward a thunderstorm on the northern horizon. When he viewed the individual TV frames he found twin flashes of light lasting about 0.03 second and extending from cloud top to about 20 km above the ground. He concluded that tropospheric electrical phenomena could extend into the ionosphere. Several weeks later he confirmed the July result while observing thunderstorm activity to the south of his observing site. To analyze the frames of the TV records, Winckler had personally assembled the necessary equipment in his home. He also used his home laboratory to produce camera-ready copy for his publications at a savings to himself of several thousand dollars.

The work of Winckler and his students on upward lightning galvanized several atmospheric research groups into developing major programs, some including suitably instrumented aircraft, to further investigate the phenomenon of cloud-to-ionosphere lightning. Funding agencies soon began to receive proposals of up to $1 million to support research on cloud-to-ionosphere lightning. Winckler's total investment had been no more than $20,000. Several of the groups starting up research programs turned to Winckler for advice on designing observing programs.

From his home, the O'Brien Observatory, and lakeside camp sites—always facing northward for the best viewing—he continued to photograph auroras with still and movie cameras. Many friends and colleagues throughout the world received prints of these superb photographs, often on "Season's Greetings" cards. In this way he continued his long-time interest in combining aesthetics with science.

IN ADDITION TO his contribution to the section on John Winckler's Echo project, Professor Paul Kellogg made many helpful comments on other parts of this memoir. Frank McDonald and John Naugle also made helpful suggestions.

HONORS AND AWARDS

1962	American Institute for Aviation and Astronautics, Space Science Award
1965-66	Guggenheim fellow, France
1972	Doctor honoris causa, Universite Paul Sabatier, Toulouse, France
1978	Arctowski Medal, National Academy of Sciences
1985	Soviet Geophysical Committee International Geophysical Year Commemorative Medal
1991	NASA Medal for Exceptional Scientific Achievement
1996	Member, National Academy of Sciences

NOTES

1. Active magnetospheric experiments include introduction of ion clouds into the magnetosphere and injection of fast electrons along geomagnetic field lines.

2. When Winckler arrived at the University of Minnesota, he set up a Geiger-Mueller tube fabrication facility there. Each of his early graduate students underwent the rite of measuring the count rate versus applied voltage of dozens of Geiger-Mueller tubes to ensure each one had a broad count-rate "plateau."

3. *J. Geophys. Res.* 65(1960):R3515-19.

4. Except for the last paragraph, this section was written by Professor Paul J. Kellogg of the University of Minnesota.

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1980

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1985

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