THE A.W.A. REVIEW

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THE COVER
George Batterson (W2GB, ex 8TC), the first president of the A.W.A., demonstrating his 1 kW rotary spark transmitter which he constructed in 1920. The receiver is a DeForest Interpanel. Taken about 1965.

Photo Credit: Al Crum

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FOREWORD

It has been stated that "Museums are the memory of man and the record of his triumphs and achievements". This memory applies both to the recorded word and to artifacts representative of man's efforts. The Antique Wireless Association, with its interest in electric communication, has encouraged both the preservation of artifacts and the documenting of history relating to this field. It has established, near Rochester, N.Y., an outstanding museum of radio communications, with artifacts representing a time span ranging from the beginning of wireless to modern television broadcasting. The library includes books, magazines and other publications describing the technical development of the radio and electronic art.

The A.W.A. has also instituted awards recognizing merit in the documenting of communications history, and for the collection and preservation of significant artifacts in this field. The Association, for many years, has published a quarterly journal called the "Old Timer's Bulletin" which has served to foster interest in these activities. With this new publication, THE A.W.A. REVIEW, the A.W.A. is recording important historical material which, because of its scope, cannot be published in the Bulletin. It is hoped that these documents will be of lasting historical significance and of interest to the majority of the members of the A.W.A. Future volumes of the REVIEW will be published at approximately yearly intervals.

Sparta, N.J. 
August, 1986 

Robert M. Morris
Fig. 1. Bruce Kelley (W2ICE, ex-W8ACY) in the original barn museum (1952). His photographic interest has resulted in numerous slide and 16mm movie film documentaries which have been shown world-wide.

Fig. 2. Members renovating the second barn museum at Holcomb, N.Y. A large factor in the Association's success has been group participation.
THE FOUNDING AND DEVELOPMENT OF THE
ANTIQUE WIRELESS ASSOCIATION
AND ITS MUSEUM

By Charles M. Brelsford, K2WW, Past President, AWA
Rochester, N.Y.

In 1936 an avid young radio amateur, Bruce Kelley, living in Rochester, N.Y., became interested in radio tubes and started to collect them, along with other early equipment. By 1948 he was residing in Spencerport, a town near Rochester, with a museum set up in his barn. He exhibited many of these items at the 1948 Hamfest of the Rochester Amateur Radio Association (RARA), and in 1952 introduced the use of photography at a RARA Old Timer's Nite. The successful combination of artifact exhibits and slide-show created an immediate demand among amateur radio organizations for more of the same. Since the exhibits, shows and museum required much time and effort, Kelley, with George Batterson and Linc Cundall, in 1952 formed a small club called the Antique Wireless Association.

Bruce Kelley, like so many others, became interested in radio when in high school. His first project was to construct a receiving set to listen to broadcasts. Then, by listening to amateurs, he learned the code and procedures so he could operate his own station. Very soon he had a license and was participating in many radio activities - talking to amateurs in foreign countries, contesting with others, building specialized equipment, and joining with other amateurs at the local radio club. Then he became interested in vacuum tubes - how they were presently used, and how they were employed back in 1915. Naturally, he continued to collect tubes and wireless apparatus used in the early days.

George Batterson was an amateur who, as a boy of fifteen, was influenced by the use of radio when the Titanic sank in 1912. After World War I George built his famous synchronous rotary spark transmitter which is now in the A.W.A. Museum. In school he studied drafting, pattern making and shop work so he was able to build many of the parts of his transmitter. He made the condenser of plate glass and brass plates and immersed both the condenser and transformer in a tank of oil. This transmitter was very effective, so effective, in fact, that it brought the radio inspector from Detroit to make measurements. Alas, the decrement could only be brought down to ninetenths, whereas seven-tenths was the limit. So, in 1922 George retired the spark set and built a tube transmitter. Thereafter, he was very active with his new radio, using code transmissions almost exclusively.

Linc Cundall began his radio career in 1916 in Hamburg, N.Y. He graduated from Worcester Polytechnic Institute in electrical and mechanical
Fig. 3. The second barn museum was divided into three areas. This is the lower level.

Fig. 4. The original officers at the annual business meeting in 1971. Left to right, top row: Cliff Daykin, Harry Lott, George Batterson, Larry Triggs, Joe Marsey, Ken Gardner, Ducké Dengler, and Hank Blogett. Kneeling: Lic Cundall, Dex Deeley, Lauren Peckham, Harold Smith, Sherwood Snyder, and Bruce Kelley.
engineering. From 1937 to retirement he worked for Eastman Kodak Co. as a machine design engineer. Line was a skilled instrument maker and applied his talents to the restoration of historic radio apparatus. His replica of the United Wireless Tuner is a classic. Line was also a good business man, who said, "I think my biggest contribution in the early days of A.W.A. was to convince Kelley that he should not put out a magazine every month."

Kelley stated he formed the A.W.A. because he had a barn. Batterson said, "Bruce came over and I told him that I had a lot of old gear. He was living in Spencerport...and he had quite a collection of various tubes. We went out to the garage, and when he saw the spark transmitter he just fell in love with the thing. So I suggested, why don't you take all this equipment home and let's get a museum started there."

By 1954 the A.W.A. was flourishing. George Batterson was president, Bruce Kelley secretary, and Linc Cundall the treasurer. There were six other Board members - Chuck Brelsford, Ducke Dengler, Gene Handler, Walt Malone, Earl Peacox and Andy Rutherford. The membership totaled 155. Of these, 57 were from Rochester, 61 were from New York State outside Rochester, and 37 were from various parts of the country and overseas. All members were radio amateurs.

In 1958 Kelley moved to Holcomb, New York and, of course, the museum collection moved with him. A fine carriage barn on the new property became the A.W.A. museum, and Holcomb, twenty miles southeast of Rochester, became the organization's headquarters.

The A.W.A. was very busy from 1958 to 1975. The Old Timer's Bulletin was established in 1960, and the famous A.W.A. National Conference started with a meeting in 1963. In 1969 the New York Board of Regents granted the A.W.A. a provisional charter for three years. The officers were Batterson, President; Brelsford, Vice-President; Kelley, Secretary; Cundall, Treasurer.

At the expiration of the provisional charter the A.W.A. did not fully qualify for a permanent charter, but in July 1972 it was incorporated as a not-for-profit organization under the laws of New York State. The officers at that time were Charles Brelsford, President; Kenneth Gardner, Vice-President; Bruce Kelley, Secretary; and Linc Cundall, Treasurer. As of December, 1972 there were thirteen Directors.

In January, 1960 the first issue of the Old Timer's Bulletin was published. Bruce Kelley was, and still is, the editor. The publication started as a monthly which was sent to all known amateur radio historians. The first issue, Vol. 1 #1 (not an official A.W.A. publication), was two sheets of dittoed typewritten material. Vol. 1 #2 was issued in February, 1960 and Vol. 1 #3 in April, 1960. Favorable reception of the Bulletin resulted in its becoming the Official Journal of the A.W.A., to be published quarterly. Vol. 1 #4 in October, 1960, was an eight-page $5\frac{1}{2}'' \times 8\frac{1}{2}''$ printed booklet. In contrast, Vol. 26 #4 in March, 1986 had 44 pages and was sent to over 2,800 members worldwide. The Old Timer's Bulletin, after 26 years of publication, continues to be the outstanding source of information for the radio historian and collector. Prominent
Fig. 5. Exterior view of the present museum housed in the historical Bloomfield Academy built in 1837. A.W.A. shares the building with the local historical society.

Fig. 6. West side of main room. Material in this area is subject to change each year. At far left is a 30'' Nipkow scanning disc used by Dr. E.F.W. Alexanderson in his early television experiments. Immediately in front of the disc is a rare 1915 Alexanderson alternator obtained from RCA's Rocky Point station. Baird, Jenkins and other receivers make up the television display.
historians have assisted in editing specific columns: i.e., vacuum tubes, keys, loudspeakers, and communication receivers. The Bulletin, of course, also serves to inform members about A.W.A. activities such as the national Conference and various special meets around the country. Many reviews have been published about famous people in the radio field, as well as articles about radio companies of historical note and their products.

The mechanics of publishing and mailing the Bulletin are significant. After the Editor has prepared the material it has to be made camera-ready for the printer. (In the early days, Bruce had the help of Larry Triggs, an advertising executive, now deceased.) When the paste-up is ready, Don Ray, the printer, prints, collates and staples the bulletins. Then Dick Fish alerts ten retiree members who prepare and mail them to the members.

The A.W.A. has published and assisted in the publication of many historical records, as for instance, the assistance given in the publication of Gerald Tyne's Saga of the Vacuum Tube. Also, eight monographs about the history of wireless have been published by the organization.

Equally important are the slide-tape shows prepared and used by the A.W.A. to provide programs for various meetings around the country. As mentioned previously, Kelley started these shows in 1952. He used his photographic skills to take pictures of collection artifacts, special events, people and historic places. These slide shows, with taped sound, usually running 45 to 60 minutes, tell stories in an interesting way. Biographical shows about Marconi,Pickerell, Armstrong and others have been prepared. Several shows tell of early amateur radio operation, such as significant DX achievements, and amateur radio clubs, through the American Radio Relay League, have used many of these shows at their meetings.

In addition, Al Crum, the official A.W.A. photographer, made sets of prints and a slide show depicting the artifacts on display in the Museum. Members bought one hundred sets of the slide show and used them for meeting programs.

As a result of the endeavors of Kelley and Crum, the media began to give the A.W.A. publicity. Magazines and newspapers have printed articles, and TV stations have featured the Museum on special showings.

Of particular significance have been the A.W.A. Annual Conferences. The first such meeting occurred in 1963 at Holcomb, New York, with attendees from fifteen different states. The program started Friday evening with a movie on the Tuckerton, Sayville, New Brunswick and Marion long-wave stations. On Saturday afternoon recognized leaders in the radio field gave talks. In the evening the attendees gathered at the Holloway House for dinner and a talk by Lloyd Espenschied, a charter member of the I.R.E. Each year since 1963, Conferences have been held as follows:

1964 New England Wireless Museum, East Greenwich, R.I.
1965 Gray History of Wireless Museum, Mason, Ohio
1966 The Franklin Institute, Philadelphia, PA
1967 The Ford Museum, Dearborn, Michigan
Fig. 7. The east corner of the main room. The A.W.A. Museum is a popular tourist attraction and a Mecca for the radio collector and historian.

Fig. 8. A section of the WW I wireless room with a replica of a 1925 radio store in the background. The 1918 receivers are at the left, and in the center is a 1kW Marconi spark transmitter.
The scope of the Annual Conference has increased greatly over the years. The program for the 1985 Conference extended from Wednesday evening through to the banquet on Saturday night. There were eight talks, a "Show and Tell" session, an "Amateur Radio Seminar", a communication receiver auction, a vacuum tube auction, and the big general auction of old radio equipment. In addition there was an outstanding old-equipment contest and display, an open-house at the Museum and Annex, and a flea market, probably the largest antique radio market in the country. Attendance at the Conference has also increased, with over eight hundred attending in 1985, including members from Europe, Africa, Asia and Australasia.

At the Annual Conferences over the years, the A.W.A. has presented special awards. Recipients of the Houck Award for Historical Documentation have been Thorn Mayes, Bruce Kelley, Gerald Tyne, Louise Moreau, William Breniman, Howard Schrader, Ralph Williams, Donald DeNeuf, Ivan Coggeshall, Lloyd Espenschied, Alan Douglas, Kay Weedon, Floyd Paul and Hugh Aitken. Recipients for the Houck Award for Collecting and Preservation have been Ed Raser, Robert & Nancy Merriam, Warren Green, Stewart Davis, Wayne Nelson, Vance Phillips, Lauren Peckham, Joseph Pavek, Ralph Muchow, John Caperton, Fred Hammond, Bro. Patrick Dowd, Rex Matlack and Ralph Williams. Other special awards are the Tyne Award for vacuum tube collection and history, the Elle Award for construction of receivers, the Matlack Award for early transmitters, the Taylor Award for television documentation, and the President's Award for support of the A.W.A. Also at these Conferences other awards have been presented for the preparation and display of historical radio equipment and documentation.

In addition to its Annual Conferences, the A.W.A. has promoted and assisted in meetings of historians and amateurs throughout the country. Many members unable to come to Canandaigua have held meetings, usually one-day events, in diverse parts of the country. Meets have been held in New England, the Carolinas, Texas, Indiana, California (north and south), Minnesota, and western New York. At many amateur hamfests the A.W.A. has maintained a special display, as has been done at the Rochester Hamfest since 1952. For years there has been a booth at the hamfests in St. Petersburg, Florida, and Gaithersburg, Maryland.

For many years members from overseas have attended the Annual Con-
Fig. 9. The 1901-1908 British Marconi ship's wireless room. An original 1901 Marconi coherer/decoherer and polar relay with tape register are in the foreground. A multiple tuner can be seen on the table with a magnetic detector mounted on the wall. At right is the familiar Marconi 10” spark coil transmitter. Adjacent to this room is a complete 1909 United Wireless shore station with original components.

Fig. 10. A British Marconi detector unit. The operator had a choice of 4 mineral detectors or a Fleming valve. This is an example of the many pieces of Marconi equipment in the Museum.
ference. Consequently, in 1984, an international conference was held in England under the auspices of the British Vintage Wireless Society. Attendance included members from the Continent as well as from the United States.

The history of the A.W.A. collection dates back to the founding of the A.W.A. Bruce Kelley’s collection of tubes, receivers and transmitters in his barn in Spencerport became the core of the eventual collection, which grew as members and the public at large donated or loaned additional items. By 1970 the carriage barn in Holcomb was full and overflowing into other barns around the area, and the Board of Directors decided to find another more suitable location for a museum, which could be open to the public. Studies were made of potential locations, sizes and types of buildings, etc. After lengthy investigation, the Board leased for a term of ten years 1,500 sq. ft. of space on the second and third floors of the Academy Building owned by the East Bloomfield Historical Society. The 1837 Academy Building, previously used by the Grange, needed complete refurbishing. The East Bloomfield Historical Society repaired the roof, pointed up the brick work, repaired windows and installed a new furnace. Extensive carpentry, rewiring, and painting had to be done in the area to be used by the A.W.A., and this work became a major project for A.W.A. volunteer members. Bruce Roloson, an expert in commercial electrical wiring, repeatedly traveled from Horseheads to supervise and assist others in replacing the electrical system. The new Museum, opened in May, 1975, has provided a very satisfactory place to display the A.W.A.’s outstanding collection. The Museum, open to the public from May through October, is staffed by member volunteers. New displays and improvements take place each year. More than 3,500 people visited the Museum in 1985, including special groups such as school classes and amateur radio clubs.

Through the years the A.W.A. has enjoyed a sound financial structure. The principal income comes from membership dues, the major portion of which is expended on the Bulletin. Other operating expenses are relatively minor so that the annual dues have been kept modest. Messrs. Cundall and Deeley have been very proficient in attending to the economy and utilization of A.W.A.’s funds.

Two major expenditures have occurred. The first was for the establishment of the Museum in 1975. A separate Museum Fund was created, started by a major contribution from Grote Reber. This fund has also received contributions from many members and from many special projects, such as a percentage of the Auction sales. While operating expenses for the Museum have increased greatly, income from the Fund’s investments provides for its satisfactory operation. The second major expenditure was used for a storage building, popularly called the Annex. This building, located on one acre of land leased for ninety-nine years from the American Legion, provides 2,400 square feet of space. Equipment which may be duplicate or supplemental to that in the Museum is stored here. Other equipment, unsuitable for public display but of special historical interest, is also stored here where members may work with it. The Annex is now nearly full.

Two noteworthy changes in policy have occurred. First, prospective members need no longer be licensed radio amateurs, but they must be in-
Fig. 11. Western Union Telegraph Office. The Association has over 1000 early telegraph instruments and keys. The keys are displayed in three large showcases. Included are landline keys dating from 1848, early siphon recorders, and very early glass dome stock tickers.

Fig. 12. The 1922 amateur station on the third floor. Starting at the left is a 1922 transmitter using UV-202 and 203 tubes with a chemical rectifier power supply. Various receivers of the period are in the center with two high power spark transmitters at the right. In front of the window is a rare 1000 watt Clapp-Eastham Hytone set, and at the far right is W2GB's sync rotary transmitter. Not seen are four additional spark transmitters. At the entrance to the room there is also a complete Collins station of modern design (KWM-1/75A-4), which operates under the call W2AN.
interested in the history and collection of early wireless apparatus. Second, a younger set of officers directs the organization. In January 1983 the following were elected and still hold office, except for Linc Cundall, now deceased. Lauren Peckham of Breesport, New York, was elected President. For many years he has been active in the affairs of the A.W.A. and has become an authority on vacuum tubes, as well as early broadcast radio receivers. The other officers elected were Bruce D. Roloson, 1st Vice-President; Richard W. Fish, 2nd Vice-President; Richard G. Ransley, Secretary; Dexter T. Deeley, Treasurer; Lincoln A. Cundall, Comptroller; and Bruce Kelley, Curator.

As one reads this exciting story of the development of The Antique Wireless Association and its activities, he realizes that it was the interest, enthusiasm, labor and devotion of Bruce Kelley and the many others who have made the A.W.A. the outstanding organization it is today.

Photo Credits: Al Crum and Bruce Kelley

Fig. 13. The big event in A.W.A. activities is the Annual Conference, held each fall. Historical papers and demonstrations in addition to a large flea market, auctions, and equipment contests make up the three-day program. This is a scene from the closing banquet at the 1980 meeting.
Nikola Tesla and quarter-wavelength antenna transformer secondary used in conjunction with a 250-kHz primary oscillation circuit (1896)

Photo credit: Nikola Tesla Museum
JOHN STONE STONE ON NIKOLA TESLA’S PRIORITY IN RADIO AND CONTINUOUS-WAVE RADIOFREQUENCY APPARATUS

Prepared and edited for publication
by
Leland I. Anderson
Denver, CO

FOREWORD —

In January 1900 Nikola Tesla brought back to New York from Colorado Springs many amazing photographs showing his experimental station (and himself included!) engulfed with electrical discharges of prodigious length. When he sent prints of these photographs to Lord Kelvin, Sir William Crookes, Sir James Dewar, Roentgen, Lenard, Slaby, and others, they cable him expressing wonderment at how he produced such effects. Some of Tesla’s experiments certainly involved disruptive-discharge circuits resulting in damped wave trains, but it may come as a surprise to many that the prime focus of his work was the production of undamped (or continuous) waves. The problem of producing high energy continuous waves for radio transmission occupied Tesla’s attention from about 1890, and the giant Wardenclyffe plant that he constructed on Long Island during 1901-1905 was designed using unique apparatus to produce continuous waves in the range of 1,000 Hz to 250 kHz.

Knowledge about Tesla’s work had been severely limited because, as an independent inventor, he conducted his work in secrecy and did not associate himself with a business enterprise that could have perpetuated the record of his accomplishments. However, writings are surfacing from special archives showing his work antedates that of many others in radio and allied arts.

A heretofore unpublished 1915 study by John Stone Stone, a theoretician and inventor together with the contemporaries of whom he writes, presents the development of radio from the beginnings, about 1888, through the teens. It is most welcome when we can benefit from the astute observations of someone such as Stone who, as a participant in the emerging radio art, saw clearly the interrelationships of those developments in the context of that period. Although distance in time may lend a broader perspective in historical analysis, unfortunately such distance removes us from the event context and most surely involves some distortion or faulty perception. Of special note, therefore, Stone’s study contrasts with the perceptions of “inventor” of radio in several of today’s ‘distant’ historical analyses.
In his study, Stone focuses on Tesla’s work in continuous-wave technology with no more information available to him than then existed in the open literature. This fact gives strength to the probability that Tesla’s work in continuous waves has been largely ignored by contemporary historians because of the great publicity given in commercial journals and the popular press to the disruptive-discharge mode of operation for the coil named after him.

Stone traces Tesla’s work in continuous-wave technology from high frequency alternators, the oscillating arc, and the rotary gap, and shows how he brought these together into a continuing developmental plan for wireless telegraphy (radio). The operating characteristics of these devices are not provided by Stone in his paper but can be briefly described from records that have only recently been made available.

Tesla’s patent *Method of Operating Arc Lamps*, #447,920 dated March 10, 1891, includes the design of a high frequency alternator drawn from a machine he constructed with 384 poles capable of producing a 20-kHz sinusoidal current of 30 amperes. This patent is a rather odd place to find the methodology disclosure of such an advanced alternator design, just as his patent for the coupled-coil system named after him is found under *System of Electric Lighting*, #454,622 dated June 23, 1891.

The rotor of the alternator held one layer of a 1-mm square conductor which was baked on forming a monolithic assembly. The field assembly was quite narrow providing great ventilation in order to accommodate a high field current and thereby produce a high current output. Fessenden and Alexanderson did not achieve such an output with their machines until 15 years later. Tesla used this alternator to drive the coils in the first two of his “trio-series” of high frequency demonstration lectures at Columbia College in 1891 and in London in 1892.

A second patent *Alternating Electric Current*, #447,921, also dated March 10, 1891, presents a different form of the alternator. Tesla intended that an alternator of this design be driven by a turbine at rotational speeds up to 20,000 rpm. Shown in Photograph 1, the field held 480 poles and wire conductors were stripped from the armature. The output conductor in the machine was but 1.25-m long with a resistance of 0.025 ohms. In this design, now over 90 years old, Tesla achieved continuous waves of 30 kHz at 25 kw with a comparatively low rotational speed.

On a point of related interest, the so-called Goldschmidt alternator (not covered in Stone’s paper) was a commercial machine utilizing the construct of Tesla’s patent *Dynamo Electric Machine*, #390,721 dated October 9, 1888, in which the field is excited by rotating magnetic field in one direction and the alternator is rotated in the opposite direction. Tesla objected to the use of this machine for his wireless work because of the high harmonic content of the output.

Stone brings into the history of continuous-wave technology development Tesla’s important work with the oscillating arc. An example of his oscillating arc apparatus is shown in Photograph 2. Consider the general receptivity of
advanced technology demonstrations that he made in the third of his trio-series of lectures at St. Louis in 1893 utilizing such apparatus: Tesla remarked, “There was a hall with six or seven thousand people. When I explained that a bulb was going to spring into light, and the current was turned on and it did burst into light, there was a stampede in the two upper galleries and they all rushed out. They thought it was some part of the devil’s work.”

Stone describes Tesla’s work with rotary gaps beginning in 1893, but the discussion does not extend to include a group of seven patents titled Electric (or Electrical) Circuit Controller, all dated August 16, 1898. The basic approach for these was a high speed rotational element in combination with a liquid conductor (typically mercury) within a hermetically sealed chamber, usually evacuated. An example of one of these is shown in Photograph 3. Two subsequent Tesla patents under the same title(s) dated October 4 and November 8, 1898, embodied an advanced approach out of which emerged a rotational continuous-wave machine constructed in 1899 and which was used in his Colorado Springs experimental station later that same year.

The details of the advanced approach referred to above were never described in patent form. The continuous-wave machine is shown in Photograph 4 and was capable of producing up to 600 cycles of current per revolution, or up to 100 kHz at 10,000 rpm, and at 37 kw with 85 percent efficiency. From the experiments at Colorado Springs, Tesla evolved the design for the continuous-wave transmitter installed at Wardenclyffe shown in Photograph 5.

Concerning Stone’s discussion of Tesla’s work and priority in the complete system for radio, anticipation by Tesla in the radio art was eventually confirmed by the U.S. Supreme Court decision of June 21, 1943, on Case No. 369 of the October 1942 term. This case, instituted by the federal government, sought to declare the fundamental Marconi radio patent invalid using the patents of Tesla, Stone, and Lodge to prove anticipation. The Opinion of the Court has been misread by a number of prominent writers. Beginning at page 14, the Opinion shows that the Tesla patent, above all others, presents the original concept and apparatus for the basic system of radio transmission/reception. This patent antedates any patents of Stone, Lodge, or Marconi on the basic system. Two specific features of the Marconi patent, one on antenna design and the other on a method of adjustable tuning, neither of which were particularized and claimed in the Tesla patent, were defeated on the basis of anticipation shown by the patents of Stone and Lodge, respectively. For a meaningful interpretation of the findings by the Court, it is necessary to review not only the decision within the context of the panoply of events surrounding the case but also the technical arguments that are presented in the Transcript of Record.

Stone neither claimed the invention of the basic radio transmission/reception system nor asserted it as shown by the following from his testimony:

Q: “Mr. Stone, you have taken out numerous patents in this and allied arts, have you not?”
A: (Stone): “I have.”
Q: “And have you not, in some of those patents, asserted that you were the inventor of this subject matter (a disclosure of a system for transmitting signals or intelligence by means of electromagnetic waves comprising a radiating conductor and a source of alternating electrical energy or potential associated with the radiating conductor, the conductor and source being coordinated and adjusted to generate and radiate a substantially continuous stream of electromagnetic waves of substantially uniform strength)?

A: (Stone): “Never, except limited to waves of a simple harmonic character or of a single periodicity, or specific character of wave radiated.”

[Stone’s 1915 study follows]

Signals Through Space — From the Beginnings

Concerning the scientific and practical application of the phenomena of natural electrical oscillations, there seems to have been no well recognized use of the phenomena until 1888-1889 Dr. Heinrich Hertz conducted his famous experiments involving for the first time the conscious and deliberate production of electromagnetic waves. This he did by setting up natural electrical oscillations in electrical conductors or circuits specially designed, first, to radiate these waves and, second, to permit their natural frequency being accurately predetermined mathematically from their dimensions, either from the formula of Lord Kelvin for simple circuits containing a coil and a condenser or by the formula developed by Heaviside and others for oscillations along cylinders or along wires.

While Hertz used natural electrical oscillations at his source, he used a resonant electric circuit, i.e., a circuit adjusted to respond resonantly to the frequency of the forced oscillations developed in it by the electromagnetic waves coming from the source. Hertz made use of resonance in his receiver in order to amplify the forced vibrations in it to such an extent that they would produce observable sparks at a micrometer spark gap, which he used as an indicator. In other words, he secured at this spark gap the cumulative effect due to the resonance of his receiver. Dr. Hertz’ work was published by himself in 1888 and 1889.

Another brilliant series of experiments with natural electrical oscillations, though overshadowed by the work of Hertz, was begun by Sir Oliver Lodge in 1888 and continued for a number of years. In this work, Lodge, in general, employed lower frequency of oscillations than Hertz and such part of his work as was not of the nature of a verification of the Hertz experiments was effected by the discharge of condensers of Leyden jars through circular conductors or coils and resulted in the production of frequencies of the order of 3 to 10 millions. Lodge’s syntonic Leyden jar experiments were begun independently of Hertz and with the object of investigating the effects of lightning, and some of his later work in the line of natural electrical oscillation and radiation is given in a paper “On Electrical Radiation and Its Concentration by Lenses” read on May 11, 1889, before the Physical Society of London.
Tesla oscillating-arc generator set (1893)

Photo credit: L. Anderson
The next (after Lodge's experiments in 1888) application of natural electrical oscillations, and this application was conscious and deliberate, was in the brilliant and fascinating series of experiments of Nikola Tesla, described by him in his various papers before the American Institute of Electrical Engineers, the Institution of Electrical Engineers at London, and the Franklin Institute at Philadelphia and the National Electric Light Association at St. Louis in the years 1891, 1892, and 1893. The subject matter of these papers by Tesla is given almost in extenso in a book entitled *Inventions, Researches and Writings of Nikola Tesla*, by Thomas Commerford Martin, published in 1894 by The Electrical Engineer, New York,¹⁷ and some of this work, especially the higher frequency dynamos developed by Tesla at this time and his suggestions for the use of high frequency currents in wireless communication, are amplified in certain United States patents of Tesla which will be referred to later.

In these experiments the natural oscillations of electric circuits were employed for the production of very powerful high frequency currents and potentials for a great variety of useful purposes including wireless communication. The frequencies of the natural oscillations employed by Tesla were far below those employed by Hertz, yet considerably above audio frequencies, while the high frequencies which he generated by dynamo machines corresponded to audio frequencies from 5,000 up to the extreme upper limit of audibility, say 30,000. By audio frequencies, which is a recent term introduced by Dr. Goldsmith, is meant frequencies corresponding to the rates of vibration of air in the production of audible sound. This includes the range of frequencies roughly between 16 periods a second to 30,000 periods a second.

It is difficult to assign definite values to the frequencies of natural oscillation secured by Tesla in many of his experiments,²⁵ but from the nature of the apparatus used, the well-known Tesla coil, it is evident that these oscillations were of the order of hundreds of thousands per second as compared with hundreds or even thousands of millions as used by Hertz and Righi in their investigations.

Elihu Thomson about that time paralleled some of Tesla's work, and these two experimental geniuses brought the apparatus for producing natural electrical oscillations of frequencies intermediate between audible frequencies (30,000), and Hertzian frequencies (10 millions), to a very high state of perfection.

**Continuous-Wave Apparatus Development**

It was not long after Tesla had revolutionized the electrical transmission of power through his invention of the rotary field motor that he turned his phenomenal skill as an experimentalist and fertility of imagination as an inventor to the development and utilization of high frequency currents.

He appears to have been led to this by the idea that since he had made it practicable to transmit power to great distance by alternating currents, he would try to make this form of current more applicable to arc lighting than it
Example Tesla continuous-wave controller (1898)

Photo credit: L. Anderson
had theretofore been. Arc lights, when used on alternating current circuits, gave out a disagreeable humming sound and it occurred to Tesla to obviate this by the use of currents of very high frequency. This he succeeded in doing. In order to secure high frequency alternating currents he designed high frequency dynamos, the first of these giving a frequency of 10,000 periods per second and later machines attaining frequencies of 20,000 to 30,000 periods per second. Tesla referred to his alternators as giving 10,000 alternations per second and some have interpreted this to be 5,000 complete cycles.*

Two types of the Tesla high frequency dynamos are illustrated and described in the Martin book. These are also set forth in the United States patents to Tesla numbered:

447,920 granted March 10, 1891, on an application filed October 1, 1890, and
447,921 granted March 10, 1891, on an application filed November 15, 1890.

![High frequency dynamo covered by Tesla patent #447,920](from the Martin book)

One of the most remarkable features of this extremely early work of Tesla is the refinement of detail with which he worked out his apparatus. A careful examination of the types of high frequency dynamo generators he designed, constructed and operated between the years 1891-1893, shows that they embodied every fundamental characteristic known to the construction of a high frequency generator except, perhaps, such slight refinements as have been found

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*In the early nineties we used the term alternations in a different sense from that in which it is used today. When we spoke of a dynamo giving 10,000 alternations in those days we meant a dynamo giving 10,000 cycles or complete to and fro surges of current a second. Nowadays an alternation has come to mean a half cycle or single reversal of current, so that what we called 10,000 alternations would today be called 10,000 cycles or 20,000 alternations.
High power continuous-wave controller used by Tesla in Colorado Springs (1899)

Photo credit: L. Anderson
Tesla Wardenclyffe transmitter (1903)

Photo credit: L. Anderson
necessary in the recent work of Alexanderson to produce the latest 200,000 frequency machines. There seems to be no reason why machines built on the Tesla lines should not be capable of giving at least as much as 50,000 complete alternations per second and perhaps considerably more. I refer particularly to the machine described in United States patent #447,921.

After using the dynamo-generated high frequency currents for a time, Tesla decided to attain even higher frequencies and the result was the invention of the Tesla oscillator. This oscillator is illustrated and described in considerable detail and in a variety of forms in the Martin book and is disclosed in his United States patents numbered:

462,418 granted November 3, 1891, on an application filed February 4, 1891,
454,622 granted June 23, 1891, on an application filed April 25, 1891,
514,168 granted February 6, 1894, on an application filed August 2, 1893,
568,176 granted September 22, 1896, on an application filed April 22, 1896,
568,178 granted September 22, 1896, on an application filed June 20, 1896, 568,180 granted September 22, 1896, on an application filed July 9, 1896, 685,012 granted October 22, 1901, on an application filed March 21, 1900, and 723,188 granted March 17, 1903, on an application filed July 16, 1900.

But Tesla effected great improvements in the detail of oscillation transformers, and one of these details has later been found of great utility and wide application in conjunction with the use of the Tesla transformer in radio telegraphy transmitters for some years. I refer to the rotary spark gap. It is disclosed in Tesla's United States patents #514,168, #568,176, #568,178, and #568,180 to which I have just referred.\(^v\)

Even the recent and very practical means now so successfully used on our Pacific Coast for transoceanic telegraphy and which has also been successfully used for radio-telephony, through the generation and radiation of a continuous stream of waves of normally constant amplitudes, is merely one form of the Tesla oscillator referred to above. It is that form in which a direct-current dynamo is used to supply the charging current to the condenser in the oscillating circuit of his oscillator. The means for producing the transverse magnetic field across the spark or arc gap and the means for immersing the spark or arc gap in an atmosphere of ionized hydrocarbon vapor, which is characteristic of the most approved form of this method of continuous generation of low frequency waves, is particularly illustrated in Figures 166 and 167 in the Martin book.

The Complete System

As early as February, 1893, Tesla suggested a system of wireless communication in which the transmitter consists of an "insulated body of large surface" elevated above the surface of the earth and a source of high frequency currents having one terminal connected to the elevated insulated capacity area and the other to the earth, and he further suggested that the source might be an "alternating dynamo machine" if the frequency desired were to be low, or if the desired frequency were high an "electrical oscillator" would be required. This electrical oscillator, or oscillation transformer, was afterwards adopted by Braun in 1898, by myself in 1899, and later by Marconi in 1900 as the source of oscillations in all radio transmitters.

Tesla's early United States patents which relate most explicitly to radio transmission are numbered:

1. 613,809 granted November 8, 1898, on an application filed July 1, 1898,
2. 645,576 granted March 20, 1900, on an application filed September 2, 1897,
3. 649,621 granted May 15, 1900, on an application filed February 19, 1897 [sic, i.e., 1900?],
4. 685,012 granted October 22, 1901, on an application filed March 21, 1900,
723,188 granted March 17, 1903, on an application filed July 16, 1900, and 787,412 granted April 18, 1905, on an application filed May 16, 1900.

I wish, of this group of patents, to particularly call attention to #723,188. This illustrates, so far as its sending and generating apparatus is concerned, an up-to-date Marconi transmitter using the rotary break re-discovered and re-named by Fessenden the "selector."

It is interesting to note that Tesla makes this disclosure at that early date of this modern, up-to-date transmitter as merely incidental to a system of avoiding at the receiver the troublesome interference from extraneous influences which still plagues radio telegraphy, but that is because he felt that he had already sufficiently disclosed these features of his system in applications previously filed. Thus, in most of his radio transmission patents he shows as a generating source the symbol

![Diagram](image)

commonly used for a dynamo but which he says in United States patent #645,576 may be a Tesla oscillation transformer operated by his rotary spark gap giving 5,000 sparks per second.

From the detailed description of the "electrical oscillators" capable of giving either sustained oscillations or damped trains of oscillations, and the detailed discussion of the high frequency dynamo, we are left in no doubt as to the form of electrical oscillators or the forms of dynamos he intends to use in his transmitter or even as to the order of the frequencies in either case. He evidently intended to use a dynamo for frequencies below 30,000 and an oscillator for frequencies above 30,000. In the case of the dynamo, his transmitter would diagrammatically be illustrated by Figure 1, but in the case of his oscillator, it would be diagrammatically illustrated by Figure 2 and 2a if a sustained train of oscillations were to be used, and by Figure 3 if a damped train of oscillations were to be used.

Considering prior art, the first published disclosure of a system for transmitting signals or intelligence by means of electromagnetic waves comprising a radiating conductor and a source of alternating electrical energy or potential associated with the radiating conductor, the conductor and source being coordinated and adjusted to generate and radiate a substantially continuous stream of electromagnetic waves of substantially uniform strength, I find in the Martin book under the subheading entitled "On Electrical Resonance," pages 340-349 inclusive, taken in conjunction with the disclosures in the rest of Chapter 28 of that book, having particular reference to the systems of generation illustrated in Figure 165 of that chapter to the devices illustrated specifically in Figures 166 and 167 of that chapter, and also having reference to the dynamos described and illustrated in connection with Figures 97, 98, 99, 199, 200, 201, 202, 203, 204, 205, 206, and 207 of the Martin book.
Tesla high frequency oscillating arc generators
[from the Martin book]
In Figure 1, $P$ is an "insulated body of large surface," $E$ is a "ground," and $S$ is a source of alternating voltage in the sending conductor.

In Figure 2, $S$ is an oscillating arc situated in the powerful magnetic field between the two poles $n$ and $s$ of a magnet and preferably immersed in an atmosphere of hydrocarbon vapor; $C$ is a condenser, and $R$ is an adjustable resistance or other means for controlling the supply of continuous current from the dynamo $D$.

In Figure 2a, $T$ is a Tesla transformer, the other reference letters referring to the same elements as in Figure 2.

In Figure 3, $g$ is a spark gap, $C$ is a condenser, $T'$ a step-up transformer, $G$ a low frequency alternating current dynamo, and $T$ a Tesla transformer.
Further, Tesla accurately describes how to adjust the frequency of the source in order to produce resonance. In describing the tuning of this system, Tesla says (Martin, p. 347):

"By varying the frequency of the currents and carefully observing the potential of the insulated body and watching for the disturbance at various neighboring points of the earth's surface resonance might be detected. Should, as the majority of scientific men in all probability believe, the period be extremely small, then a dynamo machine would not do and a proper electrical resonator would have to be produced and perhaps it might not be possible to obtain such rapid vibrations. But whether this be possible or not, and whether the earth contains a charge or not, and whatever may be its period of vibration, it certainly is possible — for of this we have daily evidence — to produce some electrical disturbance sufficiently powerful to be perceptible by suitable instruments at any point of the earth's surface."

When Tesla came to apply for patents for the system of wireless telegraphy which he had suggested in his lectures, he not only disclosed the same transmitter suggested in his 1893 papers and illustrated by my Figures 1, 2, 2a, and 3 with added details as to construction and adjustment of his transmitter, but he also described a detector to enable the high frequency received currents to act on sensitive indicating mechanisms. The indicator he describes is, in effect,
what we now call a "tone wheel," or "tikker," and which is a highly sensitive device capable of highly cumulative action when used as described by him. It may be said to be practically the only efficient type of detector for the reception of undamped waves that we had until the discovery of the oscillating audion which transcends all other detectors in sensitiveness and convenience. His United States patents disclosing this device are numbered:

685,953 granted November 5, 1901, on an application filed June 24, 1899,
685,955 granted November 5, 1901, on an application filed June 24, 1899, and
787,412 granted April 18, 1905, on an application filed May 16, 1900.

I am mindful of an experiment conducted by Tesla and his assistant George Scherff in 1897 wherein a transmitter comprising an audio frequency generator of continuous alternating current was associated directly or indirectly in an antenna with an antenna consisting of a wire leading from the laboratory to the roof, at which point it was connected to a capacity area, the lower extremity of the system so connected being grounded through a water pipe. This transmitter operated at 5 kHz and 1/4 kw input and the antenna being tuned to the frequency of the alternator, and from this sending equipment signals were received at the distance, from New York City to West Point, of 30 miles, in a receiving circuit made resonant to this frequency. These received signals could not have been effected in any other way than radio telegraphy.

Other Workers in the Art

The production of continuous trains of waves of uniform amplitude from radio transmitters did not have to wait either for the production of practical supra-audio frequency dynamos or for the working out of a practical scheme of frequency changers with which to multiply the frequency of audio-frequency dynamos. The continuous-wave radio generation was worked out on the principle of the oscillating spark or arc. Tesla, as I have pointed out, was first to describe the means for successfully producing continuous supra-audio frequency currents in this way, but his device was overlooked and was partially rediscovered by Duddell in 1900, who only succeeded in getting audio frequencies, and the complete rediscovery was made by Poulsen in 1902.

In Marconi's famous paper on "Syntonic Wireless Telegraphy," which appears with discussion in the May 17, 1901, issue of the Journal of the Society of Arts, page 551, Marconi says:

"...My first trials were not successful in consequence of the fact that I had not recognized the necessity of attempting to tune to the same period of oscillation (or octaves) the two electrical circuits of the transmitting arrangement (these circuits being the circuit consisting of the condenser and primary of the Tesla coil or transformer, and the aerial conductor and secondary of the transformer)."

Mr. Marconi appears to have been ignorant of Tesla's own disclosure of such a transmitter and of my own work in this connection.
For many years any radio station which did not use the Tesla oscillation transformer in its transmitter has been considered archaic, the extremely recent and isolated cases of stations using high frequency dynamos or dynamos and frequency changers, of course, being excepted.

It may be said that for a time after the beginning of the application of Hertzian waves to wireless telegraphy, the extremely high frequencies used seemed to differentiate them, in the popular mind especially, from the earlier experiments of Edison, Dolbear, and Tesla, but with the removal of the spark gap from the antenna, the development of earthed antenna, and the gradual enlargement of the size of stations as it was realized that greater ranges could be obtained with larger power used at lower frequencies, the art returned to the state to which Tesla developed it, and the high power and low frequency wireless station today is essentially the Tesla station in structure and operation — and the theories now adopted by radio engineers in explaining its operation are in all essentials the same as those developed by Tesla.

On the original patent application in wireless telegraphy filed May 29, 1901, by Professor Reginald Fessenden which resulted in United States patent #706,737 granted August 12, 1902, the Examiner, in a letter dated July 2, 1901, asks “whether [Fessenden] contemplates using a dynamo furnishing a current whose frequency is 100,000 per second, and if so, the nature and structure of such dynamo.” He, not being practically skilled in the art and having Tesla and his high frequency dynamos and wireless telegraph patents in mind, jumped to the conclusion that Fessenden intended to go Tesla one better on high frequency dynamos in radio telegraphy and suggested it to Fessenden.

There was no suggestion of a high frequency dynamo in the original application. A careful reading of it by one skilled in the art at that date would never have led to the assumption that this applicant intended to use anything in the way of a dynamo other than those dynamos, simple enough of construction, which would give moderate audio frequencies, say 1,000 periods per second.

On examination of the correspondence between Fessenden and the engineers of the General Electric Company, it appears that Fessenden had no idea of undertaking the development of a radio frequency in contradistinction to an audio frequency generator prior to the date when the Examiner suggested this idea of using a radio frequency dynamo directly in the aerial or sending conductor in his office action of July 2, 1901. In fact, this correspondence does not show that he began to even consider this practical development of such a radio frequency dynamo until long after the date when he filed his amendment in answer to said office action, and introduced for the first time any allusion to a radio frequency alternator in contradistinction to an audio frequency dynamo.

The Examiner’s official action of December 6, 1901 (in answer to a second amendment dated November 15, 1901), cited the Tesla patent #649,621 of May 15, 1900, and all the claims except the first were rejected on this patent to Tesla.

This letter of the Examiner is well worth careful reading as a whole. I shall
only quote a few passages. It is surprising that Fessenden was not made to limit himself to the first claim of his original application or else be put into interference with the Tesla patent in question.

"It is interesting to note that the results claimed by [the] applicant [Fessenden] in view of what has heretofore been accomplished by others in the art of wireless telegraphy indicate a very strong probability that [the] applicant has done on a small scale what Tesla proposed to do on a large scale, namely, to transmit sufficient power to produce mechanical effects as distinguished from obscure magnetic molecular or electrochemical effects heretofore produced in a coherer. By some method of electrical power transmission, this applicant [Fessenden] claims to have been able to produce physical bodily movement of mechanical parts, as for instance, deflection of the galvanometer shown in the companion application, whereas no one before him, except Tesla, has been able to transmit over considerable distances sufficient power to accomplish anything more than actuation of [a] coherer relay. The gap between the amount of power necessary to actuate a coherer and that necessary to deflect a galvanometer is so enormous as to suggest the probability of a difference in mode of transmission rather than merely a difference in degree, and to lend considerable color of probability to Tesla's theory that there is a phenomenon of conduction in apparatus designed according to the rules laid down. Both devices are adapted to spread electromagnetic waves in all directions and it is very difficult to see how an electromagnetic wave spreading in all directions differs from conduction in all directions. Tesla hoped and perhaps may be able to limit conduction to two dimensions by connecting with an upper shell of the air of sufficiently high conductivity to practically short circuit the lower air strata, but this is obviously something over and beyond and in addition to rather than different from or contradictory of what [the] applicant [Fessenden] has done.

"There is certainly nothing clearly antagonistic in the theory presented by Tesla and the theory presented by [the] applicant [Fessenden], and in any event antagonism of theory where apparatus is identical is entirely immaterial, for it is well settled that an incorrect theory of operation is not fatal to the validity of a patent for an apparatus or to the validity of an anticipatory reference. Applicant [Fessenden] seeks a patent for the apparatus and the apparatus is anticipated."

It was not until Fessenden answered the office action in July, 1901, that the word "resonance" appeared for the first time in his specification. From that time on his specification was full of resonance.

**Mode of Propagation**

Dolbear and Edison, whose systems anticipated the Hertz radiation experiments, would very naturally adopt the common mode of explanation of electric phenomena and ignore the then hypothetical and purely mathematical electromagnetic wave theory. But these various systems, all having tall, vertical transmitting antennae, bearing insulated capacity areas at their upper extremities, and being connected to the ground through sources of alternating
current, must be compared as to their mode of operation with a due regard for the difference in the mode of expressing the same electrical phenomena which were current at different epochs in the rapidly evolving electric science and arts.

Marconi, receiving his inspiration from the experiments of Hertz and Righi in electrical radiation and therefore impressed with the electric radiation aspect of the subject, regarded his transmitter entirely from the standpoint of a radiator of electromagnetic waves and it was a long time before he seemed to appreciate the real role of the earth in the operation of his system, though he early recognized that the connection of his oscillator to the earth was very material value. Tesla, on the other hand, approaching the subject of wireless telegraphy from a standpoint of his own powerful high frequency current experiments and their ability to transfer large amounts of energy in open circuits, regarded his transmitter from the point of view of a generator of high frequency currents and potential waves in the earth. Both were justifiable explanations of the same phenomena taking place in the Tesla and Marconi transmitters and of the two points of view, Tesla’s electric earth waves explanation was the more serviceable in that it explained the important and useful function of the earth, whereby the waves were enabled to travel over and around hills and were not obstructed by the sphericity of the earth’s surface, while Marconi’s view led many to place an altogether too limited scope to the possible range of transmission by the system of grounded, vertical antennae.

I refer to an article by Tesla in The Century Magazine in its issue of June 1900, pages 175-211, and particularly to that section entitled “Wireless Telegraphy - The Secret of Tuning - Errors in Hertzian Investigations - A Receiver of Wonderful Sensitiveness.” Here as elsewhere, Tesla takes a fling at those who attribute the transfer of the energy of these high frequency currents to a distance as a process of radiation. In this he was more than half right, and whatever error be made in this connection was a failure to recognize that electromagnetic waves guided by the earth’s surface, and therefore accompanied by currents in that surface, are in a sense still radiation, and that the two explanations of the phenomena are supplemental of one another and a comprehensive explanation of the phenomenon includes both the conception of the gliding electromagnetic waves and the currents in the earth’s surface.

I misunderstood Tesla. I think we all misunderstood Tesla. We thought he was a dreamer and visionary. He did dream and his dreams came true, he did have visions but they were of a real future, not an imaginary one. Tesla was the first man to lift his eyes high enough to see that the rarified stratum of atmosphere above our earth was destined to play an important role in the radio telegraphy of the future, a fact which had to obtrude itself on the attention of most of us before we saw it. But Tesla also perceived what many of us did not in those days, namely, the currents which flowed way from the base of the antenna over the surface of the earth and in the earth itself.

Appreciation

Tesla, with his almost preternatural insight into alternating current
phenomenon that had enabled him some years before to revolutionize the art of electric power transmission through the invention of the rotary field motor, knew how to make resonance serve, not merely the role of a microscope to make visible the electric oscillations, as Hertz had done, but he made it serve the role of a stereoptician to render spectacular to large audiences the phenomena of electric oscillations and high frequency currents. It is worthy of note that in all these experiments he used frequencies from 10,000 to a few hundred thousand. He did more to excite interest and create an intelligent understanding of these phenomena in the years 1891-1893 than anyone else, and the more we learn about high frequency phenomena, resonance, and radiation today, the nearer we find ourselves approaching what we at one time were inclined, through a species of intellectual myopia, to regard as the fascinating but fantastical speculations of a man whom we are now compelled, in the light of modern experience and knowledge, to admit was a prophet. But Tesla was no mere lecturer and prophet. He saw to the fulfillment of his prophesies and it has been difficult to make any but unimportant improvements in the art of radio-telegraphy without traveling part of the way at least, along a trail blazed by this pioneer who, though eminently ingenious, practical, and successful in the apparatus he devised and constructed, was so far ahead of his time that the best of us then mistook him for a dreamer.

I never came anywhere near having an appreciation of what Mr. Tesla had done in this art until a very late date, in fact, until I commenced this study of the art.

Footnotes.
1/ This classic work by the third president of the AIEE is available from several reprint publishers.
2/ For the experiments in the 1893 lecture that were not wireless telegraphy in character and which are described in Martin's book under the subheadings "Impedance Phenomena," "On Electrical Resonance," and "On the Light Phenomena Produced by High Frequency Currents of High Potential..." (pp. 338-370, and specifically with reference to the experiments represented by Figures 183a, 183b, 183c, and 196), it is obvious by Lecher observations that the frequencies employed by Tesla in these specific experiments were in the microwave range of 300 to 3,000 million.
3/ Tesla soon thereafter obtained eight additional patents on significant improvements in rotary gap apparatus. These are #609,245, #609,246, #609,247, #609,248, #609,249, and #609,251 of August 16, 1898, #611,719 of October 4, 1898, and #613,735 of November 8, 1898.
4/ Patents #645,576 and #649,621 were originally filed under an application dated September 2, 1897. The application was divided by the Patent Office, and part of the application was resubmitted February 19, 1900, resulting in patent #649,621.
5/ A form of interrupter used in the early days of radio as a detector for continuous waves consisting of a rapidly rotating connected-segment commutator and associated brush(es).
JOHN STONE STONE

John Stone Stone was born in Dover, Virginia. A graduate of Johns Hopkins University, he began his career in 1890 with American Bell Telephone Company at Boston and witnessed the first of Tesla's famous trio-series lectures on high frequency, high potential alternating currents in New York in 1891. In 1899 he opened an office as consulting engineer and in 1901 formed the Stone Wireless Telegraph Syndicate, later the Stone Telegraph and Telephone Company. Stone became especially interested in Lee de Forest's audion as an amplifier and made the first reference to it in a published paper. After arranging for a demonstration of the audion amplifier to American Telephone and Telegraph Company officials in 1912, Stone and de Forest formed a business association. Stone was a leader in forming the Institute of Radio Engineers (which later merged with the American Institute of Electrical Engineers to form the Institute of Electrical and Electronics Engineers), becoming president in 1914-1915 and was awarded its Medal of Honor in 1923. In observing his passing in 1943 the IRE expressed in eulogy, "Very much of an individualist, possessed of an interesting personality, of an artistic temperament, a gracious sense of humor, and a high sense of honor, Stone lived a good life. Stone was one of the last of the pioneers who witnessed the very inception of radio and gave his whole life to it and lived to see it flower into a great industry."

Sources —

AT&T Bell Laboratories Archives; archives of Knight Brothers, Attorneys at Law, New York; George H. Clark Radioana Collection, Archives Center, National Museum of American History, Smithsonian Institution; and Nikola Tesla Museum, Belgrade, Yugoslavia.
Among contributors to the development of electronic television was Philo Taylor Farnsworth. He was born on an isolated farm near Buckhorn, Utah, on August 19, 1906. From this rural background, this boy would conceive a system of sending pictures, without wires, from one point to another at the age of fourteen. It was his inventions which were to prove the basis for the electronic system of television that was presented to the American people in 1939.

Farnsworth was the eldest of five children. He played with lizards, prairie dogs, and read the pages of the Sears, Roebuck and Co. catalogue with great interest. His imagination was fired with pumps, lights, and other related farm items that required electricity for their operation. The catalogue was the impetus for young Farnsworth’s first recorded experiment—a perpetual motion device.

Farnsworth’s father worked with his son on many projects. Among these was one that could track the skies with bamboo poles and string. Philo learned to recognize the planets and principal stellar constellations. As Farnsworth grew, so did the scope of his reading. He read more and more scientific magazines. Because of this interest in science, he declared at the early age of six that he too wanted to become an inventor.

Farnsworth read of Einstein’s theory of relativity, the Michelson-Morley experiment, and the meeting of scientists in 1918 to test the Einstein theory. By 1918, the family moved to Rigby, Idaho. It was here that Farnsworth was to direct his thinking toward the use of the electron as a basis for a television system with no moving parts. He had read of experiments using magnets to change the path of a stream of electrons, the light produced when electrons struck a fluorescent screen, and now he began to clarify his thoughts toward this method of television.

He enrolled in school and met the chemistry teacher, Justin Tolman, who lent him many scientific books. Soon Tolman and Farnsworth spent long hours after school discussing scientific information. When not involved with school work, Farnsworth began to relate the photo-electric cell and the cathode-ray tube into one device. This device was known as the dissector tube. It was the heart of his system of television. In March or April of 1922, Farnsworth explained to his mentor, Tolman, his new television system.

The Farnsworth system of television employed a cylindrical tube closed at each end by a flat surface. Through a clear window the picture would be pro-
jected into a photosensitive coating of the rear plate of the tube. By varying the light intensities of the picture on the photoelectric surface to the front end of the tube, the scanning process would take place.7

The scanning process consisted of an anode finger that projected up in the tube to act as a collector of electrons. Magnetic scanning coils would be energized to attract and repel the electron image back and forth over an anode. One set acted to move the image in a horizontal direction and another acted to move the image vertically, as the lines were scanned. The horizontal would move at a more rapid pace while the vertical movement would be slower.8

The receiver was a cathode-ray tube shaped like a pear. The current would flow through and heat a filament in the stem and give off electrons which were the invisible cathode beam. The beam would strike the fluorescent surface lining the opposing bulb end of the tube, exciting it and causing it to glow.9

In 1923, the Farnsworth family moved to Provo, Utah, prompted by the better educational opportunities to be found there. In Provo, Farnsworth met his cousin, Arthur Crawford, who was to help in the education of the younger Farnsworth.

Farnsworth began his college education but was soon forced to find employment in order to support his mother and family after his father's death. Leaving Provo, Farnsworth found employment in Salt Lake City at Feld Electronic, owned by Lamont Field.10 He soon left this and with the help of his future brother-in-law, Clifford Gardner, set up his own radio shop. The repair work was sparse and he was forced to register at the employment agency.

Through the employment agency, he was directed to a possible position at the Community Chest. It was at the Community Chest that he met his future financial backer for his invention of television. George Everson, employed by the Community Chest in an organizational capacity, was to become interested in the ideas of Farnsworth. After several discussions, Farnsworth disclosed his television system to Everson and another Community Chest organizer, Leslie Gorrell. Both were interested and the initial funding of five thousand dollars was secured.

Farnsworth wanted to be near the California Institute of Technology. Before the move, Farnsworth married Elma Gardner on May 27, 1926 and boarded a train for Southern California. The first laboratory was located in an apartment on New Hampshire Street in Hollywood. The handwritten journal of Farnsworth revealed that his television system was composed of four components: the electro-light relay, a magnetic image dissector, a magnetic image builder, and a dissector-cell combination.11

As the summer of 1926 slipped away, drawings were made and preparations drawn for patent applications. Patent attorneys were secured and, after considerable trouble, an additional 25,000 dollars was located as the research continued. The system was tested by local university professors and found to be workable.

Another move, this time to San Francisco, was planned. The new patent at-
Attorneys in the office of Charles S. Evans were engaged to handle the complex patent applications. Donald K. Lippincott was the new attorney and worked closely with the Farnsworth laboratory.

In 1930, success followed success. Developments were made in the slope wave generator, pulse synchronization, electron multiplier, current multiplier, dissection without an anode screen, gas filled dissector, and the narrow wave band. By now, several local newspapers began to carry stories about the work of Farnsworth. As a result, many sponsors began to overrun the laboratory attempting to cash in on the new medium of television.

In April of 1930, Vladimir K. Zworykin arrived for a three-day demonstration. Zworykin spent April 10, 1930 to April 13, 1930 in the Farnsworth laboratories. Zworykin was shown the entire Farnsworth system in operation during his visit. At the initial meeting in the laboratory with several members of the staff Zworykin remarked, "This is a beautiful instrument. I wish that I might have invented it."

The months passed quickly and on August 26, 1930, Philo Farnsworth obtained two patents on his system of television transmission and reception. These patents (No. 1,773,980) issued for a television system, and (No. 1,773,981) a television receiving system were followed by additional patents that covered many phases of the development of the Farnsworth system of electronic television.

As successful tests continued, the financial problems of the laboratory grew. This situation was solved when an agreement was reached with the Philco Company of Philadelphia, Pennsylvania. In June of 1931, the necessary licensing was completed and Farnsworth and his staff made ready for the move eastward. This would bring him closer to the testing that Zworykin was conducting at Camden, New Jersey.

The number of patents grew as the research continued in the Farnsworth laboratories. One fear of most inventors is that of a patent interference case. Such an interference was brought by Farnsworth against his principle rival, Vladimir K. Zworykin and the Radio Corporation of America on May 28, 1932.

The case (No. 64,027) charged that the Farnsworth patent (No. 1,773,980) which was for a television system that included scanning under the control of straight line wave form, and also the broad idea of image dissecting, was interfered with by the Zworykin application filed in 1923. Testimony was obtained from Farnsworth, Justin Tolman, and others involved with the laboratory works since the mid 1920s. Zworykin and members of his staff testified for the RCA system of television.

The basis for the interference rested on a claim in the Farnsworth patent. This was that the Farnsworth apparatus formed an electrical image and means for scanning each elementary area of the electrical energy in accordance with the intensity of the elementary area of the electrical image being scanned. The case began on January 18, 1933 and soon oral testimony was taken from the principles in the case.
The final hearing was held on April 24, 1934 in the United States Patent Office. The Examiner ruled in favor of Farnsworth and awarded priority of invention on his system of television. The decision was based on the fact Farnsworth had defined the electrical image he created.21

The Examiner allowed one month for Zworykin to file an appeal. Such an appeal (No. 15,552) was made and a hearing was held on January 31, 1936.22 The Board of Appeals reviewed the testimony of the case and the decision of the Examiner. They concluded there was nothing to justify a modification of the previous decision rendered by the Board.23

The Board also stated that the party Zworykin does not have an electrical current image which is scanned. The Board also took the position that Farnsworth had intended his language to be limited to a scanned electrical current image. The Board affirmed the initial decision of the Examiner.24 This decision was dated March 6, 1936. There was one recourse left to Zworykin and RCA. This was the Civil Courts. Six months were allowed for an appeal, but no appeal was made within this time.

As the decade of the 1930s came to a close, negotiations with RCA to pay royalties for the use of the Farnsworth patents were concluded. RCA was licensed in September of 1939 for a period of ten years and one million dollars to use the important patents developed by Farnsworth.

As the years began their movement toward World War II, less and less information concerning Farnsworth appeared in print. Reference materials such as encyclopedias, textbooks and technical journals as evidenced today lack any significant reference to Farnsworth in their television listing.

In a page from the personal files of Farnsworth, the basic patents used in modern television receivers and transmitters are listed. These patents include scanning, synchronizing, magnetic focusing, generation of the high voltage from the horizontal scan frequency, vertical deflection wave generator, and maintaining constant black level. All of these patents were issued between 1936 and 1942.

The end of life for Philo T. Farnsworth came in March of 1971. He died in Salt Lake City at the Latter-Day Saints Hospital after suffering cardiac arrest. He was a member of the Franklin Institute, American Physical Society, Sigma X, and Eta Kappa Tu. He is survived by his widow, Elma (Pem) Gardner, and sons, Philo T. III, Russell S., and Kent M.

As a pure inventor, Philo Farnsworth’s name stands beside that of Robert Milliken, Alexander Fleming, Michael Faraday, and William Henry, Wilhelm Roentgen, Heinrich Hertz, and Edwin Armstrong.25 It was he alone that stood against the giant, RCA, and won the single court case after years and years of trials.

The list of Farnsworth patents encompasses many of the technical aspects of television today. From the scanning of the picture to the receiver, the genius of Farnsworth is evident by the electronic devices used in modern television. It can be concluded that with the addition of the Farnsworth patents in 1939, it
Philo T. Farnsworth in 1940 at the Ft. Wayne, Indiana, laboratory
was possible for the Radio Corporation and others to proceed with the commercial development of electronic television as a public service.

References


3Ibid.


8 Ibid., pp. 24-25.


10Interview with Mrs. Philo T. Farnsworth, Salt Lake City, Utah, 19 June, 1975.


15Interview with Mrs. Philo T. Farnsworth, Salt Lake City, Utah, 20 June, 1975.


23Ibid., pp. 2-4.

24 Ibid., p. 6.

A RADIO AMATEUR IN WORLD WAR I

By C. D. Tuska
First Editor of QST

The May, 1917 issue of QST, the War Number, is the starting point of this story. Amateur radio stations had been closed for the duration by Presidential Order. The Army and Navy needed a large number of radio operators, and an article in the July QST carried the headline, "Wanted: By Uncle Sam, 2000 Amateur Wireless Operators." The Navy told us that QST's recruiting efforts were most effective, and I had occasion to observe a small sample of the results. Eight amateurs in a dismantled radio shack in Illinois discussed the QST article, and 7 of the 8 enlisted in the Navy. The 8th enlisted in the Army. We'll hear more of him later.

Fig. 1. Clarence D. Tuska, taken about 1960.

By the end of July, QST had just about run out of money and had about used up its credit, and its Editor and factotum wanted a more active part in the War effort. QST was put to bed, and its editor left for Washington.

The Aviation Section of the Signal Corps said that it could use me and, because of my radio experience, it would commission me. There was a temporary restriction, though; would I please go to work as a civilian aeronautical and mechanical engineer? Could I start immediately? Would minimum pay be satisfactory? All the answers were, "Yes, sir." Little did I realize how minimal was minimum pay until I started to pay for meals at Washington wartime prices. They told me finding living quarters would be difficult and I had better start looking. I was handed a list of "available rooms," all within walking
distance. I walked first to the nearest; it was taken. I walked to the second; it was taken. I walked to the third; it was taken. The same sad story up to the sixth on the list. By then I was very tired, very warm, and very discouraged. My face must have reflected my feelings, for the sixth landlady said, "I do not have any regular room. I do have something I ordinarily would not rent, but you are welcome to look at it."

I have a vivid recollection of that "room." When the house was erected on Maryland Avenue, N.E., the builder found he had space for a most excellent hall closet on the third floor. One of the closet walls faced the avenue and was just wide enough to include a window. The landlady discovered that the closet was almost large enough to include - when exactly positioned - a small cot and a small chair. But then the door was inoperable because it opened inward. Fortunately the solution was very simple; just remove the door and substitute a curtain. Naturally the curtain was better than the door because occasionally air flowed through.

Several years later I was privileged to read Sir James M. Barrie's famous lecture on "Courage," and I doubt if many readers were better conditioned to appreciate his words. In part, at least, they applied to my stay in Washington:

"...the greatest glory that ever came to me was to be swallowed up in London, not knowing a soul, with no means of subsistence, and the fun of working till the stars went out. To have known anyone would have spoilt it. I did not even quite know the language. I rang for my boots, and they thought I said a glass of water, so I drank the water and worked on. There was no food in the cupboard, so I did not need to waste time eating. Those were the days. Too good to last..."

Major John F. Curry, later retired as Major General, directed me to prepare complete plans for a school for radio operators. How many students? No one knew. Prepare plans on the basis of a hundred. That can be multiplied by the eventually authorized number. There were plans and specifications on paper covering everything except buildings, clothing, and food. The Major must have read my recommendations because he asked me if I had not overlooked masts for aerials. I explained that radio amateurs could get things going by just throwing aerial wire into the nearest tree. He smiled and asked if I had ever been in Texas. Washington, D.C. being my farthest south, and Buffalo, N.Y. my farthest west, I answered truthfully, "No, sir." He told me trees were mighty scarce around Houston, and how right he was!

Actually, poles for aerials were my smallest worry. The greatest need was for a staff of competent teachers. Next was for some apparatus, preferably Signal Corps transmitters and receivers, storage batteries, tools, and some devices to teach code. As I worked on the paper plans, little did I realize that I would be the one to give birth to the school and to breathe life into it. I asked for authority to find and engage 10 or 12 experienced radio men for the first teaching staff. Finally the recommendation was approved, and I received orders to proceed to New York, find the men, and have them processed through the established Army organization.
By a stroke of good fortune I arrived in New York on the evening of a meeting of the Institute of Radio Engineers. The Secretary announced that C.D. Tuska was looking for experienced radio men who would eventually be commissioned in the Signal Corps, but would first be assigned to the Radio School as teaching cadets. I had just received my own commission as a Second Lieutenant, Aviation Section of the Signal Corps, Officer’s Reserve Corps, of the Army of the United States. I had taken the oath of office before leaving Washington, quickly purchased a uniform in New York, and donned it for the occasion and for the duration.

Candidates were told to report to me at the Yale Club, where a friend had put me up, starting at 9 A.M. the following morning. The response exceeded my ability to interview quickly, and I hurriedly devised a written test. It included 7 or 8 situations for which I thought I knew the answers, and I designed questions to solicit those answers. I also quite deliberately threw in a couple of questions which probably had no answers, but the way the candidates tried to answer them told me much. The unanswerables were something like this, from an entirely different field: “You are the engineer in the boiler room of a ship, the fires are going full blast, the water gauge shows no water in the boiler, the water feed valve is jammed, the safety valve is stuck and can’t be budged, steam is escaping where it shouldn’t, and there are threatening noises. What would you do?” I am told that about the only sensible answer is to sound the alarm, run to the ladder, go up as fast as possible, dash across the deck, clear the rail, dive, and then swim like hell for safety. You get the idea.

Some of the “commission seekers” took one look at the questions, handed back the sheet, and left. This saved much time. Others settled down and answered the questions with dispatch. I finally selected and approved nine. These, plus one I did not really approve, were sent to the Army Examining Board. The one not quite approved was rejected, as I believed he would be, along with one other. The remainder passed physically and mentally and were accepted. I went to bat for the rejected one because I thought he was the best radio man of the lot. But what could a Second Lieutenant do when two Captains rejected the candidate on psychological grounds? I explained that the man’s duties were to teach radio, for which he was extremely well qualified. They did not question the expert qualifications, but carefully explained that he was to be commissioned, he might be at the school for the duration, and he might have to lead men in battle, and for that he was not qualified. The answer was a firm “No.”

When I returned to Washington, I learned that Major Curry had been promoted to Lieutenant Colonel, ordered to Ellington Field at Houston, Texas, and had already left for that post. It was only a few days before I received travel orders to report promptly to the Commanding Officer, Lt. Col. Curry, at Ellington Field. How well I remember the event. I reached Houston the day before Christmas, further from home and friends than I had ever been. My orders were clear, as most travel orders are. So out to the Field I went, and promptly! The Officer-in-Charge explained that they did not expect me until after Christmas, that the Field was not quite ready, the Quartermaster’s office
Fig. 2. Air Service School for radio operators, Ellington Field, Houston, Texas, at the time of the story. In the front row, seated 4th from the left, is Elmo Pickerill, and on his left is Clarence Tuska.

Fig. 3. Radio theory class at Ellington Field.
Fig. 4. Code class at Ellington Field.

Fig. 5. Setting up a portable wireless installation. Note the row of "dummy" horses in the background.
Fig. 6. Field practice copying wireless code signals using the SCR-54. At the left is the BC-14 receiver unit, and at the right a vacuum detector using a VT-1.

was not open, there were no sleeping accommodations, no Officers’ mess, and finally I might as well go back to Houston and report back the day after Christmas. Have you ever tried to pass a whole day, let alone Christmas, in a strange city with nothing to do except sleep, eat, and read the newspapers? Eventually the day ended but it must have been 72 hours long, certainly not the conventional 24.

Ellington of 1917-18, located between Houston and Galveston, was a brand new two-unit field. The actual flying fields were each one mile square and located side by side. Along one side of each field were hangers for the training planes, mostly Curtis Jennys with 90 horsepower OX motors. Next came the main street, with barracks and other buildings strung out for nearly two miles. Headquarters was about midway in the length of Main Street, and adjacent to it was a good size building with several large rooms and a number of smaller ones. One of the largest was to be used for teaching code, while the smaller rooms were for general instruction in technical and military matters, and for laboratory use. Thus the school had appropriate space. Our cadet instructors began to arrive; now we needed equipment and the students, who would arrive in due course.

As we scrambled for supplies we organized the teaching staff. Those responsible for code designed their own system and built two code tables. A wiring
diagram reminds me that each had 40 student spaces, each equipped with a telegraph key and a set of headphones. The instructor's position included a battery operated buzzer, key, jacks, and a multiple position switch. The instructor could telegraph to all 40 positions, or selectively call any position. . . a nice device to make sure students kept awake! I cannot recall when or how they got their hands on so many keys and headphones at a time when most gear was "on order."

It seemed ridiculous that we should be frustrated by a complete lack of radio apparatus. Armed with the names of several radio amateurs, I selected first the name of James Autry, Jr. of Houston, went to his home, and explained that I would like to borrow his radio equipment for Uncle Sam's use at the Radio School at Ellington. I offered to give him a receipt for the gear. He not only had no objection, but offered to help set it up. Later I explained to the Commanding Officer what had happened, and he was so pleased that he appointed 16-year old Jimmy Autry as a radio consultant. Thus recognized, Jimmy could come to the Field at will and even get an airplane ride, which was one of the purposes of the appointment, and a most dangerous award, if you ask me now.

The Autry equipped station was operated regularly by our school personnel. We copied the 10 P.M. press, often through atrocious static, and put a typed copy at the C.O.'s place in the Officers' Mess so he could read it at breakfast. Once we passed on a weather bulletin about an unexpected freeze in our section of Texas. On the strength of the bulletin, the C.O. ordered all airplane radiators drained. The freeze came, and radio was given credit for saving the planes from possible serious damage.

At long last a ship docked at Galveston with an abundance of radio gear for all of the air fields within trucking distance. We received our share of SCR-54 receivers, SCR-65 transmitters, SCR-55 amplifiers, AR-3 antenna units, and much miscellaneous gear. Space does not permit me a description of the apparatus, which was designed for short-range operation and rough handling, and was pretty crude by the amateur standards of the day. That cavalier judgement of a World War I amateur was repeated by an amateur of World War II. It happened this way: Our own General Sarnoff and General F.N. Lanaham of the British Army decided to inspect the communication system readiness for the D-day invasion. The high point of the inspection was aboard the U.S.S. Ancon, which had a vast electronic system designed to take over communications if necessary. The visiting brass was conducted through the ship by a young signal lieutenant. In the main station there were long lines of radio receivers, many of which were made by RCA. It was natural of Sarnoff to inquire, "Which of these receivers do you consider best?"

"Not one of them worth a dime, sir", the lieutenant replied, "except this one which I built myself."

"In telling this story General Sarnoff said there was a roar of laughter, but the young man, to his credit, stuck bravely to his verdict. Then the General noted that it is typical of radio amateurs to believe that only their own handicraft is ever good enough, and "quite often they are right."

55
Returning to the 1918 apparatus: its principal purpose was to send signals from an airplane to a ground station to direct artillery fire. The ground station signaled an observer in the airplane by a visual code using several three-by-ten foot cloth strips. Generally the plane was flown toward the artillery battery, radioing the battery to fire just as the plane made a turn toward the target. An observer in the plane watched for the shell bursts around the target; then the plane was turned promptly toward the battery, indicating if the shells fell long or short, or right or left of the target, and about how far off target. The necessary gun corrections having been made, the progress continued until the target was hit.

A well-trained crew with good teamwork was a must. We simulated battlefield conditions and trained the men to install equipment and operate under abnormal conditions, such as bad interference, weak or fading signals, faulty gear, and to quickly make any necessary adjustments or repairs.

During the short time before the school was ready to receive students (they either enlisted or were drafted), they were sent to Kelly Field, San Antonio. There were thousands of men of many different skills there in early 1918, and from these I was ordered to select the first group for our radio school. When I went to San Antonio for that purpose, I found the classification records were somewhat less than complete and therefore decided to interview men whose records indicated some possibilities. I looked first for radio amateurs, second for telegraph operators, and finally for those who had some qualifications for the job.

Fig. 7. Airplane spark transmitter BC-15A installed in the rear cockpit of an observation plane at Ellington Field. The complete unit is the SCR-65.
Among the amateurs interviewed, the "eighth" amateur, already mentioned, appeared. He was none other than K.B. Warner. When the selected group was transferred to Ellington Field, Warner was made an instructor, and a good one he was. He was soon made sergeant. Later he was transferred to Officer's School and commissioned after completing the course. I remember writing to Hiram P. Maxim that I had found my successor as Secretary of the ARRL and Editor of QST. After the war, Warner came to Hartford and became the Secretary and Editor as planned. Our friendship, which started at the school, continued until his death. Of all the students, none made a greater impression on me than K.B. Warner, who was a dedicated amateur from start to finish. While there were many others in the school entitled to honorable mention, for fear of skipping some, I shall not name any.

When things were running well at the school, a trip to San Antonio and Waco in search of more qualified students was required. I had a happy idea; I explained to Colonel Curry that if the trip was made by airplane, one of our pilots could have a cross-country training flight of nearly 700 miles, and as a passenger I could get the job done quickly. The Colonel approved but said the only available plane suitable for the trip was a little known and little used L.W.F. Although he was an experienced flyer, Lt. Chase, who was chosen as pilot for the trip, was not familiar with this plane. The L.W.F. had a long, slow gliding characteristic. Chase wanted to take a few hops in the plane to get the feel of it. This he did.

A Texas map will show that Houston, San Antonio, and Waco form roughly an equilateral triangle, whose sides are approximately 200 miles. In 1918 most cross-country flights were made by following railroad lines or other determinable landmarks. Almost no cross-country flying was done using compass bearings because there was then no good way of determining drift due to indeterminate cross winds.

After lunch we set out boldly with some maps and some hopes that we could make San Antonio before nightfall. We flew for what seemed a long time, but we had not picked up the railroad tracks and I thought we were seeing too much of the Gulf of Mexico. The ground underneath was most inhospitable; no sign of a human, a highway, or a house. Finally we sighted a town, but could not identify it. Chase decided we had better find out where we were. Landing in a field close to town, we learned that it was Gonzales, some fifty miles due east of San Antonio. Furthermore, the railroad extended in an almost straight line to San Antonio; this seemed like an easy flight, so we took off. After circling the town to gain altitude, we could see the railroad and also that the sun was about to set. Lt. Chase concluded that it might not be healthy to fly over a strange city looking for a strange airfield after dark. We landed again near the town as the sun set.

This time there was a large turnout of townspeople to see what happened to be the first plane to land locally. A voice of authority asked where we had come from, where we were going, and what we were going to do. It was the Mayor of Gonzales. We explained and indicated that we would stay overnight, leaving at sun up. He offered to take us to the hotel. When we explained that
we could not leave the plane unattended, it being Government property, he offered to station a guard for the night. Chase, who outranked me, accepted the offer and left with the Mayor in the latter's car. I did not mind being outranked because that enabled me to cast my lot with two delightful young ladies, who just happened to be nieces of the Mayor. As they drove me to the Hotel, I somehow arranged a double date for the evening. That led to an offer to take us back to the plane right after breakfast.

The next morning, after thanking the guards and the girls, we warmed up the motor, waved goodbye, and took off in a low overcast. Flying just below the overcast and within easy sight of the railroad, we soon approached San Antonio. Lt. Chase noted that some of the taller buildings were partly in the fog, and decided wisely to land on the parade grounds at Fort Sam Houston. The landing itself was uneventful, but something was leaking! The L.W.F. fuel tank was just behind the engine, with a pressure feed to the carburator. The tank had sprung a leak and gasoline was being sprayed all over the motor. We both wondered then, and probably many times since, what kept us from catching fire or exploding. One sensible answer might be a special angel just assigned to watch over flyers; a sort of anti-gremlin.

My work required the better part of two days, giving Chase plenty of time to locate a mechanic who patched the tank. We finally took off to fly north to Rich Field at Waco. This proved to be the one uneventful leg of the flight. Again my work took two days. The morning of our departure was most miserable because of fog and low clouds, and we had to fly at 1200 to 1500 feet to keep within sight of the railroad tracks to Houston. The forward visibility was extremely low. I had just begun to think that only we were foolish enough to fly cross country in that soupy weather, but how wrong I was! Suddenly a plane heading north, at our altitude and using our railroad tracks, broke through the clouds. Lt. Chase dove and veered to the right. The other plane? I have often wondered if the pilot even saw us. He kept right on course and disappeared as suddenly as he had appeared.

Eventually the sun broke through, and flying became enjoyable. In perhaps an hour we should be able to see Houston, and Ellington Field would be only minutes away. We relaxed, and so did the motor. It sputtered and quit. Lt. Chase, having the choice of several empty fields, made a perfect dead-stick landing in the nearest. By that time he was tired and too disgusted with the plane even to consider looking for the engine trouble. Presently he hitched a ride to the nearest telephone, called Ellington, described our location, and requested that a mechanic familiar with the L.W.F. be flown over. Later that afternoon a plane with the mechanic arrived and landed along side the crippled craft. He quickly spotted the trouble; a pressure relief valve in the tank had failed but was easy to repair.

Chase said he would fly the L.W.F. back to Ellington, but to play safe he wanted the mechanic to accompany him, so I switched to the other plane. Late in the day both planes got off safely, but this time I was in the front seat of a Jenny, flying with an unknown pilot. By the time we arrived over Houston it was dark enough for street lights. We thought we were heading directly for
Ellington, but instead of sighting the field, we found ourselves over Goose Creek. If you are not acquainted with Goose Creek, let me tell you that it is no place over which to be lost, especially at night!

The pilot throttled back the motor and shouted, “How much gas is left?” The gasoline gauge was located halfway between the windshield and the engine. I could see its outline but could not read the indicator, and I had no means of illuminating the dial. Things looked black in more ways than one. Praying for sufficient gas, the pilot had a happy idea; he banked and turned for Houston, whose night glow could easily be seen. Once over the city, he was able to spot the Interurban tracks which were very near Ellington on their route to Galveston. Following the tracks, we soon picked up the night lights at the field.

Now we ran into a new set of troubles. Students were being trained to fly at night. Their planes had red and green wing tip lights, and there were colored signal lights on the field. Eight planes circled the field, taking turns landing and taking off in response to signals from the ground. We could see the lighted planes but they could not see us. My pilot did not panic because he knew what to do. Putting the plane in a tight circle outside the paths of the lighted planes, he kept gunning the motor. The irregular sounds reached the ears of the ground crew, who realized that someone up there was in trouble. The crew put on all their red lights, which I learned later was the signal for all planes to stay aloft except the one in trouble. My pilot guided our plane under the circling students and made a perfect landing. That special angel was with us, but was he watching over Lt. Chase? He had not been heard from. I waited awhile, and finally went to bed, but I could not sleep.

At least I should have sung that famous war ditty, “What’s the use of worrying, it never was worthwhile”, because Lt. Chase appeared the next day, having landed at Camp Travis and spending the night in comfort, albeit worrying about us. Before closing, may I tell briefly of one more flight that was the antithesis of the one just described, a one-way trip if you please.

The Signal Corps ROTC unit at A. & M. College Station, Texas wanted six small ammeters, which we could spare from stock. Colonel Curry advised me to learn to fly, on the grounds that I would be flying with trained and partly trained, and good and poor pilots, and an emergency might arise when I could have a pressing need to know how. I had followed his advice as time permitted, but needed more training. Therefore I decided that flying the meters would expedite their delivery and would provide me with an opportunity for cross-country flight training. My roommate, Lt. E.N. Pickerill (who, by the way, was the old-time commercial operator) also wanted to fly to College Station.

We picked two young flyers as our instructors. Looking back, I believe it is proper to say that they were long on flying skill and short on mature judgment. My instructor sat in the front seat so I could have the benefit of the instruments in the rear cockpit. Paying no attention to my flying, he spent the time reading a magazine and munching on Graham crackers. When we arrived at College Station he took over. There were excellent big fields near the Cam-
pus, but not withstanding these, he elected to land on the Campus. This was not impossible, but just tremendously impractical. Even with the existing headwind, we had a safety factor of less than one. With extreme skill my pilot cleared the roof of the YMCA building by, I estimated, a neat three feet. He would undoubtedly have hit the trees at the far side of the Campus but for the headwind and some alert young men, who ran out, grabbed the wingtips, and dragged us to a halt. Not to be outdone, Lt. Pickerill’s pilot accepted the dare and did the same thing with the same skill and the same luck.

It was some time before we were ready to start back. The headwind which had helped us in had shifted and was blowing across our only path out. Hindsight tells me that the Campus was much too small for a Jenny with a 90 HP engine to take off, even under reasonable wind conditions. Nevertheless, my pilot had the plane pulled back until its tail just touched the wall of the building we had hurdled coming in. The plane was held back until the motor was warmed up and running at full throttle. At a signal, the holders let go, and we bounced along on a no-turning-back course with the cross wind drifting us towards some trees on our right. The pilot held the plane on the ground until the very last moment and then eased back on the stick.

We took off and almost cleared the trees at the end of the Campus. I have never decided if the plane stalled, or if the trees wiped off the elevator control wires. By the time we crashed, I had pulled off my goggles, closed the throttle, and opened the ignition switch to minimize the chance of fire. The plane was literally folded up around the front cockpit, and the pilot was trapped in his seat. I could not pull the fuselage apart to get him out, and he yelled he was being scalded. Hot water was pouring on him from broken connections. I really expected the wreck to catch fire, but that Guardian Angel must have been hovering over us.

It seemed like a long time, but probably the dust had not settled before spectators came running to us and got my companion out. It was about six or seven years later, as I walked out of Hudson’s Dept. Store in Detroit, when a stranger stopped me and said, “You don’t know me but I remember your airplane crash at College Station.” Perhaps 19 years after the event, I was working in the RCA Patent Department in Camden in Building 5. One day, “Doc” Tolson walked in with an old newspaper clipping with a picture and an account of the crash. He had not only been at the College but was one of the first to reach the plane to help in the rescue effort. You may well wonder why “Doc” is dead and I am alive.

The second crew wanted to try the take off, I suspect to prove it could be done. I had other ideas and prevailed; an enormous field lay just beyond where we were and only a few obstacles intervened. By waiting until morning, I thought we could get enough help to get the plane over to the larger field. With noticeable reluctance, the pilot agreed. That night both instructors enjoyed a college dance, so mine could not have been hurt much after he dried out.

In the morning willing hands boosted the plane over the obstacles and on to the nearby field, which I estimated to be about one mile on each of its four
sides. There was a single large tree about in the center. The wind was blowing toward that tree, which loomed large even at that distance. Since the standard rule was to take off into the wind, I asked Pickerill’s instructor if he should taxi down wind and take off toward us. Perhaps I should have kept my big mouth shut because he allowed with such a big field it wasn’t necessary. I remember shaking my head.

He was right. He did get the plane off the ground, flying with the wind! And, yes, you’ve guessed it - he hit that one tree and completely ruined the plane. Again that overworked Angel was there so no one got hurt. Pickerill liked to argue later that theirs was a better wreck than ours. And well he might argue, as neither of us had to answer to the authorities. Moreover, we were not called as witnesses, and we never heard if our instructors were slapped on the wrist or grounded for a short period. As taxpayers, you may decide it was a most expensive way to deliver meters. A bureaucrat might say the meters were delivered with great dispatch, and a humanitarian perhaps declare that lives were saved by eliminating a couple of underpowered and therefore dangerous airplanes.

Shortly after our return from College Station, I received orders to report to Washington by the way of Lake Charles, La., where I was instructed about the latest radio-telephone equipment. In Washington I received verbal instructions about my next assignment at the University of Texas in Austin. The authorities in Washington wanted changes made in a course for radio mechanics being given at the University. The training there was to parallel what had been done at Ellington Field. My job was to select a few of the Ellington radio school instructors to assign in setting up an appropriate course of study. The necessary paper work had been done by one assistant before we requested the transfer of qualified personnel who would teach the required subjects. During my term at the University, my orders placed me on an unavoidable conflict course with the interests of the University, which may have accounted for my early transfer. As you may suspect, the military usually gets its way in wartime, as it did in this situation.

A few of the radio instructors at Ellington were transferred to Austin to get the new school going quickly. After it was operating smoothly, I received orders to report to Love Field in Dallas, Texas. I was never quite sure what I was supposed to be doing at Love field, and I was not there long enough to find out. I do remember that I had not been paid when I left Austin, and I was flat broke.

Under ordinary circumstances, being broke in the Army is not very serious, but this turned out to be one of the hard things about the War. I had met a charming girl at the University of Texas, and she invited me to visit at her home in Fort Worth, a scant thirty miles from Dallas. To this day I have never been in Fort Worth (although I was supposed to go there to take the gas mask drill in a gas chamber), because I received orders to report without delay to the Firing Center at Camp McClellan, Anniston, Alabama. I made the trip under the worst train conditions you can imagine and I guess I looked it, because a very kindly Adjutant suggested (if not ordered) that I go to his tent and shave
and freshen-up; it would just not do to report to the Commanding Officer as I was.

When I did report, I was told in a few crisp words what was expected of me, and finally, if I observed all the rules I would be permitted to eat at the officers’ mess; otherwise, he didn’t know where I’d eat! The C.O. was a West Pointer and he demanded and received West Point performance.

I was on detached service with the Field Artillery, which was about to put together a complete division, and the command wanted to train its radio operators. That was my assignment, and it required a completely new radio school.

I shall not bore you with details, such as converting a mess shack into school rooms, and finding suitable instructors and personnel. We did not have to improvise, because the division in the making had real guns (French 75’s and U.S. 4 inch) with live ammunition, firing over a hill at unseen targets. There were three airplanes with able pilots, and advisors who had been sent back from overseas to help us. We built a dugout close to the artillery battery, where our best students got real training.

The officers at the Firing Center lived in tents which could be heated with Sibley stoves. We were required to have strikers, who took care of our tents and uniforms, cared for the stove, maintained a supply of water in a bucket (which in winter generally formed a layer of ice), polished our shoes and boots, and made themselves generally useful.

I should mention the flu. We were required to wear face masks and to pass throat inspection before entering the officers’ mess. Since those who got the flu and were sent to the hospital did not fare too well, I decided in advance that I would risk even a court-martial, by staying in bed in my tent, hoping that I might recover before I was reported. I did just that, consuming large amounts of liquids in the meantime. I recovered in two or three days and resumed my duties.

During the evenings, with available news, I kept a war map of the front lines. Colored pins showed the steady Allied advance, and I was not surprised at the sudden termination in November. I was ready when it was announced that discharges could be made at the convenience of the Government. However, there was a problem. I was not in the Field Artillery, but on detached service from the Aviation Section of the Signal Corps. Could I be discharged by a general officer in another service? It seemed to me that the very best approach was to question the authority, and I must have used the right approach and exactly the right words, because the officer had no doubt of his authority, provided I could get all the minor clearances. I never worked so fast or so hard. In less than two days I had all the necessary papers, which I exchanged for a welcome honorable discharge, and travel orders to proceed to my home in Hartford, Connecticut.

EDITOR’S NOTE:
Lt. Tuska returned to Hartford, to QST and the ARRL. He apparently introduced Lt. K.B. Warner to H.P. Maxim and others at ARRL, and participated in the resumption of publication of
QST by getting out the "Midget" issue in May, 1919. The first regular postwar issue of QST was in June, 1919, in which K.B. Warner is listed as Secretary of ARRL and Editor of QST.

Following his association with ARRL, Clarence Tuska went into the radio manufacturing business, and was responsible for the design and manufacture of several miscellaneous pieces of equipment for use by amateurs. The advertisement shown from the December 1919 issue of QST, is for a storage "B" battery by the C.D. Tuska Co. of Hartford. The Tuska Co. later designed and produced some excellent radio receivers, now prized in any collection of early radio equipment. Here are two examples of these receivers.

Fig. 8. The Type 220, listed by Tuska in an early catalog as the "EXPERT" TUNER. There were two wave length ranges which could be selected by use of the switch on the lower left of the front panel: 150-385 and 375-800 meters. The cost was $75.00.

Photo credit: Lauren Peckham

Fig. 9. The Tuska Type 225 broadcast receiver in an early form. It included the Type 224 1-tube receiver and the Type 226 2-stage audio amplifier, mounted in one cabinet. The price was the same as the tuner, $75.00.

Photo credit: Lauren Peckham
A new development in vacuum tube reception has been made in this New Hi-Volt Storage Battery. The feature is a self-contained battery and rectifier. The battery has a voltage of 24 and under normal use holds its charge for three weeks. When discharged all you do is to connect a 110 volts A.C. line and in three hours the battery is fully charged and ready for use.

Economical---Efficient---Lasting

Combined Battery and Charging Rectifier as Illustrated, $15.00

Send 6c. for our catalog No. 1 and description of Hi-Volt Storage Battery.

The C. D. Tuska Company
HARTFORD, CONNECTICUT
The story of how a small manufacturer of power plant specialty items, and later toys and household items, became one of the leading manufacturers of amateur, commercial and military short-wave communications equipment is interesting and fascinating. As we will see, it was not planned that way; it just happened!

In 1879 Edison invented the electric light bulb. This created a large demand for electrical energy. Charles Steinmetz and George Westinghouse solved the mysteries of alternating current which permitted large amounts of electrical energy to be transmitted over long distances. This, in turn, created a need for large power generating stations. By the early 1900s the design and construction of power generating stations was, in today's terminology, an emerging industry.

At the turn of the century, one of the leading power plant construction companies was, and still is, the Stone and Webster Co. who then had their headquarters in the Boston, Massachusetts area.

Power plants required many hardware specialty items which were new and unique and for which no regular suppliers had yet established themselves. Three mechanical engineers from Stone and Webster recognized this market and set up a company on a part-time basis to design and manufacture these hardware items.

A material called transite was widely used at that time to make switching and transformer vaults for power plants. Transite is a sheet material, similar to plywood except that the base material is asbestos which is noncombustible and a nonconductor of electricity.

The power plant specialty business had one serious drawback; while the market with Stone and Webster was guaranteed, it was sporadic. Stone and Webster did not receive new construction contracts every day and there were long gaps between contracts when there was no demand for these specialty items. A search was therefore made for products which they could manufacture using the production tools they had and for which a steady demand existed.

One of the three knew a toy buyer for the F.W. Woolworth Company; so they went into the toy business as well as the power plant specialty business.

I have not been able to pinpoint the date when the three actually began manufacturing power plant items or when they began manufacturing toys but
it was in the 1910-14 period. On October 23, 1914 they incorporated in Massachusetts as the National Toy Company. The initial capitalization was $1,000; $700 in cash and $300, which was the evaluation placed on a patent for "talking machine toys." The incorporators were Warren Hopkins, Walter Balke, and Rosewell Douglass. Hopkins had the most money and the controlling interest in the company and always "called the shots" until his death in the early 1940s, even though he retained his position at Stone and Webster; in fact, Hopkins later became president of Stone and Webster Engineering Co. In the early toy days the company was run by Roswell Douglass; he died in the late 'teens and William Ready became the chief operating officer. He also took Douglass' place as a stock holder.

The toy business was highly successful; in June 1916, sixteen months after incorporating, the company had grossed over $33,000 and paid over $8,000 to Balke, Hopkins and Douglass. This is better than a ten-to-one return on their $700 cash investment in sixteen months and would be considered good even today, but these were pre-WWI dollars. The toys were sold through such well-known stores as F.A.O. Schwarz, Jordan Marsh, Wm. Filene, John Wanamaker, and Gimbel Bros., as well as through Victor and Columbia Talking Machine dealers. Over 8,800 of these toys were sold between January and June of 1916 and the company planned to make 16,000 more during the remainder of 1916. The early talking machine (phonograph) toys were designed by Walter Balke, who was very ingenious mechanically; the toys would be considered high technology for their day. All of the toys were attached to the turntable of a phonograph and were activated by the record being played on the phonograph. For example, 'REX the Magnetic Dog' was controlled by a resonant reed. When this reed was activated by the proper note on the record, REX would jump out of his kennel. 'The Magnetic Dancers' were small figures of dancers with steel bases that would glide on an opaque glass plate over a

Fig. 1. The Magnetic Dancers.

Photo credit: John Nagle
special record on the phonograph containing small cobalt magnetics. These would cause the dancers to glide around the ‘dance floor.’ Another series were the ‘Wireless Pups’ which I have not seen described. There was also an entire family of ‘Ragtime Rastus’ dancers including Boxers and Uncle Sam and Mex. These were loose jointed wooden figures that would dance or box on top of a revolving turntable. By choosing a record with the proper beat, a very entertaining effect could be obtained:

This success apparently created the need for additional working capital and it was proposed to issue $5,000 worth of preferred stock to be purchased by the present stock holders. The reasons for this are interesting:

“New things are constantly being brought to us, many of them specialties not in the toy line (for instance a mattress for children’s cribs and hospitals which can be readily taken apart, washed and aired, as well as other household specialties). In order that we may take up the manufacture of any profitable specialty, we shall probably when increasing the capital stock change the name to The National Company or other suitable name that will not limit us to toys.”

I have not been able to determine when that was written or when the name was actually changed but I believe it was in late 1916. On February 16, 1932 the corporation charter was further amended to formally change the company name to the National Company, Inc., by which name the company is generally remembered. Note that the word “Company” is a part of the name and should be spelled out as is the word National. The expression National Co., Inc. is incorrect.

When the United States entered World War I, the company made airplane parts and thread gauges for the war effort. At the conclusion of the war National went back to making power plant items, toys and as an added line, household items.
By the end of March 1923 the National inventory included fourteen items: T.M. Toys, Magnetic Dancers, Roberts Mixers, DMB Covers, Victrolene, Wall Rack and Plan Holders, Radio Components, S. Santry, Holophane, Thompson Spa, Portalite, H. Electric Lt, Co. Doble and Miscellaneous. I can only identify about three of them.

Fig. 4. Another National product - National Sports Skates.

Photo credit: John Nagle
ENTERING RADIO - THE EARLY YEARS

In the early 1920s several radio stations began regularly scheduled broadcasting and the public craze was to build radio receivers. The leading variable capacitor (condenser in those days) manufacturer at the time was Allen D. Cardwell, and Cardwell was not able to keep up with the demand. Cardwell's representative in the Boston area — George Q. Hill — was unhappy since he worked on commission and his income was limited by Cardwell's deliveries. Hill recognized the demand for variable capacitors and looked around for alternate sources. The management of National was always interested in new products and were eager to profit from the new radio craze. In 1922 they began supplying variable capacitors to Hill who sold them as fast as National could make them. When National later entered the radio business, Hill became the sales manager for radio products.

In 1924, two engineers from Harvard University, Fred H. Drake and Glenn Browning, developed the Browning Drake tuner which was "guaranteed" to improve radio reception; Browning and Drake approached National to manufacture the tuner. The radio editor of the Christian Science Monitor, Vulney Hurd, liked the Browning Drake tuner and gave it extensive publicity in his weekly newspaper column, so that the tuner soon became a very popular item. The National Company decided to make the design, manufacture and sales of radio equipment and components their principal line of business, and began looking around for someone knowledgeable in the fledging radio field to join the company and lead them.

In 1924 Hopkins, Ready and Balke were on a business trip to Garden City, Long Island where they were introduced to James Millen. Millen's father had recently died while the younger Millen was a mechanical engineering student at the Stevens Institute of Technology in Hoboken, N.J. In order to finish college, Millen began writing magazine articles on radio topics. For example, a "Dear Abbey" type column on radio topics regularly appeared in Doubleday's Radio Broadcast magazine in which Millen answered questions from readers on their radio problems.

Millen had begun writing at an early age. He had his first item published when he was 15 in the October 1916 issue of Popular Science Monthly; it showed how any home work shop could have a small anvil. Staple an old fashioned flat-iron upside down to the edge of the work bench. It sounds like a good idea, even today, if you can find an old fashioned flat iron!

Because of his writing, Millen had acquired a considerable reputation in radio and had built up an extensive consulting practice which included CECO in Providence, R.I. and the Spencer brothers in the Boston area who had just established the American Appliance Co., which was later to become Raytheon. When Millen graduated in 1926 he began working for National on a consulting basis and in 1927 dropped his other consulting contracts and began working for them full time as Chief Engineer and General Manager. His goal was to firmly establish the National Company in the radio business.

In 1926 the National Company needed to expand its manufacturing facilities
and acquired the factory building at 61 Sherman Street, Malden, Massachusetts, formerly owned by the Cub Knitting Mills. Cub had gone bankrupt and their factory had been put on the auction block. The attorney who was supposed to appear at the auction to set the minimum acceptable bid did not show up so the building went to National for about ten cents on the dollar.

National’s first offerings under Millen’s guidance included a Type L-3 two-stage audio power amplifier and battery eliminator which was developed in collaboration with Arthur Lynch, a Model E-1 single stage audio amplifier and battery eliminator, and a model M battery eliminator. These were announced late in 1927.

In 1929, in collaboration with Glenn Browning, National announced the MB-29 broadcast band tuner which consisted of three stages of rf amplification and bandpass tuning. In 1930 an improved model, the MB-30, consisting of four stages of rf amplification, was advertised. These were both TRF models.

THE REGENERATIVE RECEIVERS

National’s first short wave receiver was the SW-2 (stands for Short-Wave, 2 tubes) consisting of an untuned rf amplifier and a regenerative detector. The basic design was obtained from the RCA Communications Laboratory, then located at Van Cortlandt Park, New York City. Several of Millen’s college classmates had gone to work for RCA and he had extensive contacts there. The SW-2 was based on a receiver design RCA developed for an “export receiver” sold by the General Electric Co. in South America. This receiver became known as the SW-4 when it was later manufactured by National.

The SW-2 was the only receiver National made without sheet metal or production tooling; for example, all drilled holes were laid out by hand instead of using fixtures. The SW-2 was extensively advertised as a TV receiver and Millen wrote an article in the November 1928 issue of Radio News describing his TV experiments. The SW-2 appeared in late 1927 or early 1928. A three-
Fig. 6. The National Company at 61 Sherman St., Malden, Mass., about 1930.  
*Photo credit: James Millen*

Fig. 7. An interior view of the National Company, in the early '30s, showing assembly of SW-3 receivers.  
*Photo Credit: James Millen*
tube version of the SW-2 appeared in 1929; the third tube was an voltage amplifier and apparently was added to provide additional amplification for TV work.

In 1929 the company produced the four-tube SW-4, the fourth tube being an audio power output tube. A sheet metal cabinet was also provided.

As new and improved vacuum tubes were developed, National improved its receivers. In 1930 Millen and Kruse, who was a former technical editor of QST, designed the SW-5 receiver. The fifth tube was added to provide a push-pull output stage for loud speaker operation. This was one of the first short-wave receivers specifically designed for operation from AC power lines. The receiver was completely hum-free and had no dead spots which was quite an accomplishment at that time. A “high fidelity” version of the same receiver — the SW-45 — was also sold which used type 45 tubes for the audio output stage instead of the type 27 used in the SW-5.

As the country was in the midst of the great depression, a low-cost version of the SW-5 was soon developed — the now venerable SW-3. The push-pull audio output stage of the SW-5 was eliminated — which meant headphone operation only — and a wrap-around sheet metal cabinet was substituted to further reduce costs. Both AC and battery powered models of the SW-3 were marketed and two upgrades made; the last right after WWII to use octal tubes. This receiver was in production almost 15 years, from 1933 to 1948, the longest production run of any receiver except the HRO which was in production for almost 30 years. The SW-3 has become a “must” for any collector of early short-wave receivers.

One last regenerative receiver deserves mention, the SW-58C. This receiver was designed as a companion receiver for the AGS superheterodyne receiver to cover the 200 to 400 Khz frequency range used by the airlines that the AGS

Fig. 8. The famous SW-3 receiver, with a set of coils in the NCC-10 National Coil Cabinet. 

Photo credit: John Nagle
Fig. 9. Early television experiments at National, about 1927. Shown is a National SW-2 with TV scanning disc. In the background is a National RF oscillator and a Western Electric 540 A.W. speaker.

*Photo credit: National Radio Co., Inc.*
receiver would not cover. The receiver is basically the SW-58 except for the plug-in coils. These coils look like the coils used for the AGS/FB-7 receivers but they are longer and smaller in diameter. They are NOT interchangeable with the AGS/FB-7 coils. The SW-58C had a National type N dial, as did the AGS; the SW-58C is generally seen in AGS advertisements as the ‘other’ receiver in the relay rack.

THE EARLY SUPERHETERODYNES

In 1932 the General Electric Co. was awarded a contract by the recently established Civil Aeronautics Authority (known as the FAA today) to provide short-wave (HF in today’s terminology) transmitters and receivers to the Government for air safety use in the fledgling airline industry. GE had developed a transmitter but they did not have a receiver. The Western Electric Company had a receiver, but for competitive reasons GE did not want to team with Western Electric and instead approached Millen to have National design and manufacture a suitable receiver. The result was the AGS (for Aeronautical Ground Station). This was the first high performance short-wave receiver made by National and one of the first high performance receivers commercially available. Most of the receivers were sold to the CAA through the General Electric Co. A few went into the amateur market along with amateur bandspread coils.

Again the depression reared its head and in order to make the receiver more marketable a reduced version was made available; this was called the FB-7. The rf preselector was eliminated and a more economical wrap-around sheet metal cabinet was provided; only one set of coils was included so that the cost was reduced to where many amateurs could afford what was probably the first medium performance amateur superhet receiver. The receiver became very popular among amateurs and is among collectors, too.

THE HRO AND ITS DESCENDENTS

After the introduction of the AGS by the Government, the airline industry itself began to recognize the importance of reliable radio communication and urged National to develop a receiver for their use. Herbert Hoover, Jr. was then in charge of radio communications for Western Airlines (which later became a part of TWA); he acted as an informal spokesman for the airlines. The main airline requirements were that if plug-in coils were necessary to obtain the desired performance, then all coils must be plugged in simultaneously. A second requirement was two stages of preselection. As these requirements, plus a crystal filter, closely matched those desired by the amateur community for their dream receiver, the two markets could be combined into one receiver which became known as the HRO. By the way, HRO stands for Helluva Rush Order, honestly! How it got that name is part of the HRO story which is too long to include here.

The HRO was first announced in the October 1934 issue of QST and delivery was promised for December 1934 in time for the Christmas trade. The photograph shown in that announcement is the prototype model which did not
go into production. However, technical problems delayed deliveries until March 1935; the photograph shown in the January issue of QST is that of the first production model. The same basic receiver stayed in continuous production almost thirty years until October 1964 when the HRO-500 was announced. This is a remarkable life span for any piece of electronic equipment, especially one that was designed so early in the electronics age.

In February 1936 National announced the HRO Jr., a scaled down version of the HRO, at a cost of just under $100. The advertised economies were effected by removing the crystal filter, the S-meter and by supplying only one coil set, without bandspread, to cover any two contiguous amateur bands. One further economy was not advertised; with the HRO Sr. each coil set was aligned in the receiver with which it was sold. This, of course, gave an exact alignment of each coil set for each receiver. The complete alignment of an HRO Sr. required about four hours. With the HRO Jr. the coils were aligned to an average receiver and the receivers were aligned with an average coil set so that one did not have the precision alignment that was obtained with the more expensive receiver.

In August 1936, Millen announced a new receiver designed for both amateurs and short-wave listeners, the NC-100X. This basic design would be carried through in many more receiver designs, the 100XA, the NC-101 series, the NC-200 family that came out just before WWII, to mention a few. Unfortunately, time and space do not permit a detailed examination of these and many other receivers that National engineers developed. Suffice to say, that by the middle 1930s the design of high performance receivers had advanced from an art to a science and National built up a very competent engineering staff that kept National products up to date and in high demand.

**MILLEN LEAVES NATIONAL**

In 1939 lightning struck! The June 1939 issue of QST carried an announcement that as of May first, 1939, James Millen had "completely withdrawn from the National Company....." What had happened to end such a successful collaboration of almost 15 years?

The immediate reason occurred early in 1939. According to Millen, Warren Hopkins, who held the controlling interest in National, told Millen that he (Hopkins) wanted Millen to switch the emphasis of the company from making short-wave radios for a very limited sector of the country to making broadcast type radios to be marketed by the retail giants as Sears Roebuck, Montgomery Ward and the many large and well known department stores around the country. The purpose of the drastic change was to make the National Company a "household name" in the radio business.

Millen was flabbergasted!

National had been highly successful in designing and manufacturing short-wave radios; in fact, they were the recognized leader in the receiver field and more recently in transmitters and accessory items, too. Equally important, the company was profitable!
Why? Hopkins would give no definite reasons, saying only that he wanted to change the direction of the company, and the company needed products where it would have more exposure.

Millen wanted no part of it; he was dedicated to building the best receivers that he could build regardless of price. The consumer radio business was completely alien to him. So he left National and formed his own business.

From a historical point of view it is interesting to pause a moment and look back and examine what Millen had contributed to the National Company, Inc. in its transformation from a toy maker to a leadership role in short-wave communications receivers.

First, I have heard it said by people who were closely associated with National, but not employed by National, that, in the 1930s National was run by Jim Millen and his secretary Frances Bearse. Miss Bearse held the formal title of Office Manager but was apparently more of Millen’s right-hand “man.”

Second, Millen traveled extensively in those days visiting suppliers, dealers, and most important, individual amateurs and amateurs radio clubs throughout the country. When he returned to Malden, he knew what the amateur community needed and wanted. He also knew what new materials and components were available. He would sit down with his designers and sketch out new products. In short, Millen was an “idea man.”

The third role Millen played was as a publicist. As noted earlier, Millen had a flair for writing and he used this ability well. He usually wrote a magazine article describing each new product, but more than that, he would explain in simple technical terms why it was built the way it was. By the end of the article most readers would agree that the way National designed the equipment was the “only way” to do it and nobody could improve upon it.

In the March 1934 issue of QST Millen inaugurated what is probably the longest running and most successful series of technical advertisements. These were always the first advertising page in QST and consisted of a single page write-up on some technical topic of interest at the time: a description of a new receiver, a new circuit or component of something similar. This page was known as “page 73” at National regardless of the magazine page on which it was printed. This series continued through number 243 which appeared in the July 1954 QST, a run of over 20 years.

In retrospect, Millen believes Warren Hopkins’ desire to change direction was based on another consideration; Hopkins died of cancer in the early 1940s and Millen feels that Hopkins was told he had cancer in early 1939 and had only a few years to live. Hopkins wanted to convert his assets into the maximum amount of cash possible. This would be a natural reaction for any business man in Hopkins’ situation. National had a good reputation in amateur and Government circles but was virtually unknown by the general public or, equally important, by the financial community which would ultimately set the value of his holdings. This lack of recognition would tend to hold down the price of National stock.
As it turned out, Hopkins got his wish of increased value for his stock but from an entirely different direction.

In the summer of 1939 war broke out in Europe; representatives of Allied governments, particularly the Royal Navy, visited National and ordered large numbers of receivers, particularly HROs. When the United States entered the war some two years later, the word was “Start building HROs; we’ll tell you when to stop.”

Needless to say, National began producing for the war effort. The number of employees went from the 200-300 range to about 2500 during the war. The war effort brought increased recognition and profits to National and after the war, in the late forties, National went public.

NATIONAL’S POST-WAR YEARS

National built extensively on its war-time expansion and developed an impressive array of military, industrial, and consumer as well as amateur products and appeared to have a very promising future.

Effective June 1, 1953 William A. Ready retired, after almost forty years as president of National, and Charles C. Hornbostel became president. Hornbostel graduated from the Harvard School of Business specializing in accounting.

William A. Ready is remembered as a kindly person by his fellow employees at National. He knew most employees on a first name basis as well as their wife’s and children’s names. He was always available and often stopped to talk with employees on his tours through the plant. No special introductions were needed.

Ready began the tradition of holding employee Christmas parties. Former National employees still gather at Christmas to renew old friendships and memories. I have been privileged to attend several of these reunions and have found the employees treasure their memories there. National must have been an interesting place to work!

After the company went public, a controlling interest was acquired by Louis C. Learner, an investment company, and the Learner interests took control. Legal technicalities tend to obscure the facts and I have not been able to determine all the details to my satisfaction.

The new management apparently set up a second company called National Radio Company, Inc.; all Government work continued to be charged to the National Company, but now all commercial and amateur work was charged to the National Radio Company. Press releases were made detailing plans for rejuvination of the company and the price of the stock went up. At that point the Learner interests sold their stock. Several component product lines were sold to Japanese interests as was the production machinery and the name National Company, Inc. The National Radio Company went into bankruptcy and that name was sold to the bankrupt’s principal creditor, who in turn sold it to the FAN-WEL Corp., who purchased the remaining assets as well. In June 1974,
FAN-WEL changed its name to National Radio Company, Inc. and is still doing business under that name.

The Japanese-held National Company, Inc. makes consumer type radios but, to the best of my knowledge, they are not sold in this country. Warren Hopkins had his wish come true after all.

ACKNOWLEDGEMENTS

I would like to acknowledge the extensive help I have received from many sources. First, James Millen has spent many hours reviewing the early days of National with me as well as the early history of the radio industry in which he played an important part. He has provided me with many technical data sheets and magazine tear sheets on the early equipment built by National and copies of his own extensive writings. I must also recognize the cooperation of the former employees of National who welcomed me into their group; particularly Vincent and Edith Messina, Conrad Espinola, Jack Ivers and Gene Simms. It has been a real pleasure meeting these people. I would like to also thank the management and employees of the present National Radio Company for letting me browse through their files of the old National Company.

Last, but certainly not least, my wife Martha has spent a lot of time correcting and revising my manuscript and turned it into something readable.

I can not conceive that this document is free of errors, although it is based on the best evidence available to me. I will be happy to hear from anyone having more accurate information.

LIST OF EQUIPMENT

The following table lists most of the amateur and commercial radio equipment manufactured by National from 1929 to 1960 in chronological order. To save space, only the basic version of most models is listed. Some of the lesser known models as well as some of the consumer products manufactured immediately following WWII, such as TV and HiFi equipment, have also been omitted.

<table>
<thead>
<tr>
<th>DATE</th>
<th>MODEL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1927(late)</td>
<td>Type M</td>
<td>B Power-Unit</td>
</tr>
<tr>
<td>1927(late)</td>
<td>Type E-1</td>
<td>One stage audio amplifier</td>
</tr>
<tr>
<td>1927(late)</td>
<td>Type L-3</td>
<td>Power amplifier and B power pack</td>
</tr>
<tr>
<td>1928(late)</td>
<td>NJ-30</td>
<td>BC band tuner without cabinet for custom installations.</td>
</tr>
<tr>
<td>1929</td>
<td>MB-29</td>
<td>Broadcast tuner, three stages TRF</td>
</tr>
<tr>
<td>1929</td>
<td>SW-4</td>
<td>The G.E. “export” receiver</td>
</tr>
<tr>
<td>1930</td>
<td>LC-3</td>
<td>Short-wave converter</td>
</tr>
<tr>
<td>1930</td>
<td>MB-30</td>
<td>Broadcast tuner, four stages, TRF</td>
</tr>
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<td>1930</td>
<td>SW-5</td>
<td>Regenerative receiver (Thrill-Box) 5-tubes</td>
</tr>
<tr>
<td>1930</td>
<td>SW-45</td>
<td>Similar to SW-5 but used type 45 tubes for audio output stage</td>
</tr>
<tr>
<td>Year</td>
<td>Model</td>
<td>Description</td>
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<td>------</td>
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</tr>
<tr>
<td>1931</td>
<td>SW-3</td>
<td>Three-tube regenerative receiver</td>
</tr>
<tr>
<td>1932</td>
<td>SW-58</td>
<td>Up-dated version of SW-5 using type 58 tubes</td>
</tr>
<tr>
<td>1932</td>
<td>SW-34</td>
<td>Battery operation version of SW-58</td>
</tr>
<tr>
<td>1932</td>
<td>MB-32</td>
<td>Broadcast tuner</td>
</tr>
<tr>
<td>1932</td>
<td>AGS</td>
<td>High performance superheterodyne communications receiver</td>
</tr>
<tr>
<td>1932</td>
<td>SW-58C</td>
<td>Companion receiver to AGS for low frequency operation, rack mounted, type-N dial</td>
</tr>
<tr>
<td>1932</td>
<td>NC-5</td>
<td>Converter, 15 to 185 meters to the broadcast band, coil change switch</td>
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<td>1933</td>
<td>SRR</td>
<td>Super-regenerative receiver</td>
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<td>1933</td>
<td>TRM</td>
<td>Coils available 5-80 meters</td>
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<tr>
<td>1933</td>
<td>TRW</td>
<td>Transceiver, regenerative detector 56-60 mc/s. battery power, metal case</td>
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<tr>
<td>1933</td>
<td>HFC</td>
<td>High-frequency converter, 5 and 10 meter amateur bands to broadcast band</td>
</tr>
<tr>
<td>1933</td>
<td>FB-7</td>
<td>Receiver, short-wave, superheterodyne &quot;single-signal&quot;, plug-in coils</td>
</tr>
<tr>
<td>1935</td>
<td>HRO</td>
<td>High-performance superheterodyne communications receiver</td>
</tr>
<tr>
<td>1936</td>
<td>NC-100X</td>
<td>Short-wave receiver designed for SWLs and amateurs, used PW type dial</td>
</tr>
<tr>
<td>1936</td>
<td>HRO, Jr</td>
<td>Scaled-down version of HRO</td>
</tr>
<tr>
<td>1937</td>
<td>NC-101X</td>
<td>Same basic receiver as NC-100X for amateur bands only</td>
</tr>
<tr>
<td>1937</td>
<td>NC-80X</td>
<td>General coverage receiver for amateurs, ac/dc power, replacement for FB-7</td>
</tr>
<tr>
<td>1937</td>
<td>NC-81X</td>
<td>Same receiver as NC-80X but covered amateur bands only</td>
</tr>
<tr>
<td>1938</td>
<td>NC-100AX</td>
<td>Same receiver as NC-100X but with directly calibrated dial</td>
</tr>
<tr>
<td>1938</td>
<td>NC-101AX</td>
<td>Same as NC-101X except directly calibrated tuning dial</td>
</tr>
<tr>
<td>1938</td>
<td>1-10</td>
<td>Super-regenerative receiver, tuned 28-300 mc/s, plug-in coils.</td>
</tr>
<tr>
<td>1938</td>
<td>None</td>
<td>Meterological receiver build for U.S. Weather Service, Radio-Sonde reception</td>
</tr>
<tr>
<td>1938</td>
<td>NC-510</td>
<td>Based on 1-10 design, 56-85 mc/s</td>
</tr>
<tr>
<td>1938</td>
<td>NHU</td>
<td>Superheterodyne receiver, 28-60 mc/s Apparently very few made</td>
</tr>
<tr>
<td>1938</td>
<td>NHU-B</td>
<td>Superheterodyne receiver, 28-60 mc/s Apparently superseded the NC-510.</td>
</tr>
<tr>
<td>1938</td>
<td>NHU-20</td>
<td>Same as NHU but for 6 volt operation</td>
</tr>
<tr>
<td>1938</td>
<td>NSA</td>
<td>Audio speech amplifier, 15 watts output</td>
</tr>
</tbody>
</table>
1938  NT-100PC  Final amplifier for 600 watt transmitter
1938  NT-300PC  Modulator for 600 watt transmitter
1938  NT-1200PC  1250 volt power supply for 600 watt transmitter
1938  NT-2000PC  2000 volt power supply for 600 watt transmitter
1938  NT-APW  Pi Network antenna coupler for 600 watt transmitter
1938  NT-RPW  Relay control panel for 600 watt transmitter

Fig. 10. The 1932 AGS-X in a custom walnut cabinet for table mounting. The Lamb type mechanical quartz filter provided single-signal operation. Another version, the AGU, had the three coils assembled into a single unit for ease of handling.

Fig. 11. The first production version of the remarkable HRO high-frequency communications receiver. The white S-meter button was quickly supplanted by the pull switch. This model is quite rare.
<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1939</td>
<td>NSM</td>
<td>Modulator, 30 watts output, automatic volume compression</td>
</tr>
<tr>
<td>1939</td>
<td>NTE</td>
<td>RF exciter and speech amplifier covered 5, 10, 20, and 80 meter bands</td>
</tr>
<tr>
<td>1939</td>
<td>NTE-A</td>
<td>Same as NTE but covered 10, 20, 40, and 80 meter amateur bands</td>
</tr>
<tr>
<td>1939</td>
<td>NTE-B</td>
<td>RF exciter only, no speech amplifier</td>
</tr>
<tr>
<td>1940</td>
<td>NTX-30</td>
<td>4-band 30 watt CW transmitter</td>
</tr>
<tr>
<td>1940</td>
<td>NC-44</td>
<td>Superheterodyne receiver, ac/dc power</td>
</tr>
<tr>
<td>1940</td>
<td>NC-44A</td>
<td>Same as NC-44 but ac operation only B-minus return grounded to chassis</td>
</tr>
<tr>
<td>1940</td>
<td>NC-44B</td>
<td>Same as NC-44 except ac/dc or external 6 volt vibrator supply</td>
</tr>
<tr>
<td>1940</td>
<td>NC-44BV</td>
<td>Same as NC-44B but 6 volt vibrator power supply built-in</td>
</tr>
<tr>
<td>1940</td>
<td>NC-200</td>
<td>Up-date of NC-100 family, general coverage and amateur bandspread</td>
</tr>
<tr>
<td>1941</td>
<td>NC-45</td>
<td>Same as NC-44 but with noise limiter</td>
</tr>
<tr>
<td>1944</td>
<td>HRO-5</td>
<td>First model to use metal tubes</td>
</tr>
<tr>
<td>1945</td>
<td>HRO-5A1</td>
<td>Post-war amateur model, noise limiter</td>
</tr>
<tr>
<td>1945</td>
<td>NC-2-40</td>
<td>Post-war up-date of the NC-200 family, Tuning range .49-30 mc/s</td>
</tr>
<tr>
<td>1945</td>
<td>NC-2-40S</td>
<td>Same as NC-2-40 except tuning range 200-400 kc/s and .49-18 mc/s</td>
</tr>
<tr>
<td>1946</td>
<td>NC-46</td>
<td>Post-war up-date of NC-45 series</td>
</tr>
<tr>
<td>1947</td>
<td>HRO-7</td>
<td>HRO in new cabinet design</td>
</tr>
<tr>
<td>1947</td>
<td>NC-173</td>
<td>Amateur receiver, .54-31 mc/s and 48-56 mc/s</td>
</tr>
<tr>
<td>1947</td>
<td>NC-108</td>
<td>87-108 mc/s FM tuner consumer product</td>
</tr>
<tr>
<td>1947</td>
<td>NC-57</td>
<td>Low cost communication receiver</td>
</tr>
<tr>
<td>1947</td>
<td>NCTV7</td>
<td>Television receiver 7 inch tube</td>
</tr>
<tr>
<td>1947</td>
<td>NC-TV7</td>
<td>Same as NCTV7 but added “S” meter for measurement of signal strength</td>
</tr>
<tr>
<td>1948</td>
<td>NC-183</td>
<td>Amateur communication receiver .54-31 mc/s and 48-56 mc/s</td>
</tr>
<tr>
<td>1948</td>
<td>NC-183DT</td>
<td>Same as NC-183 except dual conversion above 4.3 mc/s</td>
</tr>
<tr>
<td>1950</td>
<td>HRO-50</td>
<td>Built-in power supply, slide-rule dial push-pull audio</td>
</tr>
<tr>
<td>1951</td>
<td>HRO-50-1</td>
<td>Same as HRO-50 only 12 tuned circuits in i.f. amplifier</td>
</tr>
<tr>
<td>1954</td>
<td>HRO-60</td>
<td>Similar to HRO-50-1 but dual conversion above 8 mc/s</td>
</tr>
<tr>
<td>1958</td>
<td>NC-300</td>
<td>Receiver for amateur bands only</td>
</tr>
<tr>
<td>1959</td>
<td>NC-303</td>
<td>Same as NC-300 only dual conversion</td>
</tr>
<tr>
<td>1960</td>
<td>NC-400</td>
<td>General coverage receiver. Very few sold, probably overpriced, .54-30 mc/s</td>
</tr>
</tbody>
</table>
A. ATWATER KENT
PRESIDENT AND FOUNDER OF THE
ATWATER KENT MFG COMPANY
Philadelphia
ATWATER KENT EARLY RADIO DEVELOPMENT

By Ralph O. Williams, N3VT
Orient, N.Y.

The Atwater Kent radio receivers that were built in the early nineteen twenties attract substantial attention and interest from present-day collectors, historians and students of industrial styling. Those earliest AK receivers, the Open Sets, dramatic as they appear when compared to modern radios, were nearly unique in their own time. Today, at least one Open Set, familiarly called a breadboard, is considered necessary for any radio collection that exemplifies the beginning of broadcasting. These radios, with their intriguing appearance, can tell a most interesting story about Atwater Kent and his time.

A single radio, when carefully examined and analyzed, can be the source of much information about the state of the technical art at the time of its manufacture. A series of radios, especially if they follow each other as members of a family, both in the flow of time and in the development of performance, can tell much more about the growth of the radio art and the evolution of manufacturing, distribution and use of radios in their period.

The main body of this paper is a series of descriptions and discussions of the radios in the Atwater Kent product line. It starts with the instruments which preceded the manufacture of complete radios. The Open Sets and the first of the cabinet receivers are then covered. Those readers whose main interest is in the technical characteristics of the radios themselves will find the descriptions starting in Section II. For students of the development of production in the field of radio manufacturing, Section I will discuss briefly the forces that Atwater Kent was eminently successful in harnessing to become one of the great names in radio history.

I — Before the Radios

Historians rarely have the luxury of studying extensive written records that might directly portray the specific interplay of the major forces in a technical society, especially in the fields of business and manufacturing. But the artifacts that result from the work of a major figure in these fields can often yield, upon analysis, enough of the story to provide the basis for detailed ancillary research, and at the same time make possible an interesting telling of the main technical story.

Surviving direct records of Arthur Atwater Kent, the man, are almost non-existent. Recollections by members of his family and former colleagues do exist and are being extended by oral-histories. Records of the manufacturing company for which Kent was so well known no longer exist, having been destroyed not long after the production operations were terminated decades
ago. But artifacts, the produced radios and the radio instruments made before radio production became the total business, have survived in quite extensive quantities and in excellent condition. They therefore offer an unparallel opportunity for analysis and evaluation.

Any conclusions and judgments based largely on such an artifact analysis as is necessary to portray Atwater Kent will be flawed by the one-sidedness of the story. Such faults exist in this review. Analysis of the artifacts can be as accurate as the author’s skill makes possible, but extensions to the societal forces lack sufficient verification, and must be recognized as being at best hypothetical or more accurately, postulatory.

A study of the major influences that have left clear traces in the actions of Arthur Atwater Kent illuminates the impact of forces so powerful as to almost completely reshape life in the mid-to-late twentieth century in America and Europe, even though Kent himself was not active in business after his plant was shut down in 1936.

The more important of these forces appear, at first glance, to be an odd lot: the development of very ductile steel; the extended understanding and utilization of assembly-line manufacturing; the application of modulated radio waves to the radiation of entertainment; and the increasing realization by the average early-twentieth-century citizen of the importance to him of knowledge about the rest of the world.

No single individual is ever the sole source or generator of a new way of life in a society, especially one as large as a nation. Study of the contributions of one person, however, in the development of the changes with which he is identified, facilitates understanding of that history. It leads to detailed characterization of contemporaries and of the social and technological forces that influenced the period of interest.

In a commercial field where the product is highly technological in nature, e.g., radio at the beginning of broadcasting, there was much cross-fertilization among the individual companies that competed in the general market. One reason for this was the engineering force which shared a common knowledge base and maintained close technical information exchange thru the Institute of Radio Engineers. Another reason appeared in the form of market limitation, i.e., the form of the end product and the way in which it was used. By this is meant, specifically, the transmission of cultural information via amplitude-modulated radio waves to receivers in the homes of non-technical families.

With a common technical base and common usage, the areas of individual contribution for any particular radio producer tended to be in three quite different facets of the business; product styling and identification, the means of distribution, and manufacturing sophistication and efficiency. Even these diverse aspects tended to become routine and prosaic because of such influences as customer taste and the cost of investing in product changes. Any emerging radio business had to work from the patent base controlled by the Radio Corporation, meet the usage and transmission requirements, create a strong customer demand, and in spite of these difficulties, make money. The
ways that Atwater Kent met all these demands to eventually become the record producer of radio sets reflect both the qualities of the man and the earlier experiences that shaped his career. A brief review of the early days serves well to understand the beginnings of Kent's unique line of instruments and receiving sets.

Atwater Kent started his business career very shortly before the turn of the twentieth century. He made electrical devices such as motors and fans and even a game called Amperia. In 1902 Kent moved to Philadelphia, where he produced electrical measuring instruments and a small telephone system called the Monoplex that was suitable for domestic interphone use. Although Atwater Kent manufactured electrical devices, his interests were broader than electricity. The mechanical quality of his products was very high and this could only have occurred if he were as strongly interested in the mechanical design as in the electrical function. Clearly apparent was his response to some of the technological forces operating at the turn of the century; the use of electricity to perform new services, mechanical embodiments using the best available technology, and perfection of product for both performance and reliability.

Kent's interest in things electrical and mechanical drew him to the automobile where he found and solved a problem worthy of his abilities, the generation of a precisely-timed energetic ignition spark. Early gasoline engines were generally operated at low speed, where the accuracy of the ignition spark was not a major limitation. In making improvements to engine performance, however, spark timing became a serious concern. Atwater Kent invented a means of precisely controlling both the occurrence and the duration of the spark with relation to valve and piston timing. The 1907 Spark Generator was the first unit to incorporate the very sophisticated spring-mass timing method which was later called the Unisparker, and for which Atwater Kent was awarded the John Scott Legacy Medal by the Franklin Institute in 1914. Ignition equipment produced by Kent's factory before the radio days is shown in Figure 1.

World War I brought a need to utilize the high quality and precise manufacturing capability of Kent's factory in Philadelphia for making military instruments. There he produced gun sighting and fuse setting equipment for the army. Figure 2 shows a pair of clinometers used to set the elevation angle of medium to large pieces of ordnance equipment. Also shown are three AK voltmeters and their leather cases.

Figure 3 pictures a very rare piece of precision AK military equipment, the gun-training theodolite. The device is a transit having the capability to measure or set both elevation and azimuth angles. Its optical path includes two prisms to confine the physical size of the telescope body to the dimensions of the precise leveling-screw plate that was the base of the instrument. To the left of the theodolite is its rather special case. When it was not being used for gun control, the instrument had to be cared for as a piece of precision optical equipment.

The work done by Atwater Kent on military instruments and on automobile ignition systems in the first two decades of the twentieth century brought ex-
Fig. 1. Ignition Components

Fig. 2. Clinometers and Voltammetry
perience and familiarity in several highly specialized fields: high-voltage electrical components and systems; metal working, particularly in forming steel; insulation, especially in the casting of phenolics; and the manufacture of complex parts to tight standards. The marketing of ignition systems, and later, the expansion to full automotive electrical systems, brought Kent experience in another critical area, reaching his customer base. Through his dealer sales-and-service organization he became aware that the internal-combustion automobile was reshaping the attitudes and views of people who had hitherto been limited to their neighborhoods and small communities. The average man's horizon was expanding, but as yet, the forces that ultimately came together in the form of broadcasting had not been strongly felt.

II - Instruments and Radios

At the beginning of the 1920s radio experiments, performed by amateurs and commercial wireless companies, to examine the means and values of transmitting one-way, general-interest material pointed to a potentially stunning audience. David Sarnoff had partially succeeded in getting the Radio Corporation to develop a simple inexpensive receiver, but it fell to Dr. Frank Conrad of Westinghouse to put it all together; transmission, reception and public response. With the work of these men and the many more visionaries
like them, broadcasting was born. Radio manufacturing companies, such as Grebe, modified their products to participate in the growing radio market. Companies like Eiseman and Splitdorf that had ignition backgrounds considered the radio business a suitable expansion of their interests and later joined in the production of receivers.

Atwater Kent's factory was well suited to meeting the requirements of this newly developing radio market. He and his staff had the technology, the manufacturing expertise, the business acumen to take the risks, and the vision to see the potential rewards. With no surviving records to document how AK entered the new market, the artifacts reveal that getting into the radio business was done on a progressive basis. First, instruments were designed and distributed. Careful analysis of instrument part numbers and contemporary advertisements indicates that the factory started production of radio instruments toward the end of 1921. With an active distribution system in place for the automotive-electrical product line, entering the radio business must have been relatively easy for the Atwater Kent Manufacturing Company.

Figure 4 shows the breadth of the product line. Two manufacturing techniques distinguish these instruments. One is the outstanding Bakelite casting capability and the other is the use of drawn steel containers for housing the instruments. Increasingly through the time that Kent made radios, he implemented his designs by the use of shaped steel. The degree of deep-drawing evidenced by the Type L audio transformer in the right foreground of Figure 4 demonstrates Atwater Kent's mastery of the art of shaping steel.

The inductive instruments and the amplifier-detector units were packed in cardboard boxes, that included data on the application and connection of the parts into complete radio receivers. Finished boards were also offered to enable simple mechanical assembly of a receiver using these parts. The boards were made of mahogany, edged with cross strips and finished in the brown color typical of their forerunners, the ignition system boxes.

The 3900 Series

Recognizing Mr. Kent's continuing awareness of how successfully his products were received in the market place, it is not hard to believe that he initiated production of complete radio receivers as soon as he could get his factory into position. The dates of initial production of the first factory-built receivers bear this out. The first receiver, Part No. 3925, was introduced into production in November 1922, barely a year after the separate instruments came out. Figure 5 shows one of the two versions of this set. This configuration was never sold directly by Atwater Kent. The second configuration was the same except that the variometer (the middle instrument) was not included. The reason was that the variometer made the set a regenerator, and Kent never licensed that patent from Armstrong. If a customer bought the set he got it less the variometer but with the space for it left open on the board. He then, or subsequently, could purchase a variometer, fasten it to the board, wire it to posts on the rear of the tube unit and have the benefits of regeneration. Using this means to offer the advantages of the regenerator without paying royalties
Fig. 4. Radio Instruments

Fig. 5. No. 3925
to its inventor may possibly have been Kent's intention, but a more likely explanation is that Armstrong and Westinghouse limited the number of licenses. In any case, it is an interesting sidelight of the business side of early radio development.

This radio, Part No. 3925, used the Detector-One Stage TA unit for its electronic functions. With a local station typically of 100 watts output and a 70 foot antenna, the regenerator version would have produced a loud-speaker output sufficient for a small, quiet room. The simple detector version would have been heard well only with earphones. The TA unit contained an audio transformer, the detector bias condenser, the grid leak and all the connections. From the users standpoint it was very convenient. One disadvantage was that more audio amplification was not easy to connect, so the radio was limited in growth. The next receiver in the line responded to the need for more amplification in a way that was typical of Atwater Kent.

From the data listed in one of the very few documents that survived the factory closing, the next radio receiver assembled by the factory was introduced into production one week after No. 3925. It too had a Part Number; 3945. Figure 6 illustrates the set. The difference between No. 3945 and the earlier one, No. 3925, was in the audio portion of the set where two amplifiers were found instead of only one. In both sets the audio amplifiers were incorporated in the deep-drawn metal cans. The amplifier tubes were socketed on the brown Bakelite top with the transformers buried in a protective tar fill inside the base. Since one amplifier tube and one detector were needed for the No. 3925, they were arranged along the cross-unit diameter resulting in an instrument about five inches wide on top. On the three-tube unit two transformers were buried in the tar. The two amplifier tubes were placed on a cross-unit line a little forward of the diameter. The detector was centered behind the amplifiers forming
a nearly equilateral triangle with them. This instrument was a little larger, almost six inches across the top. Again, the set was sold without the variometer to avoid infringing the regeneration patent. After purchase the owner could add the variometer, making the connections between that instrument and the P1 and P2 post behind the detector tube, as was done on the set illustrated.

The left-most instrument in line on both sets was the Coupled Circuit Tuner. It provided the means to match the antenna impedance, usually low, to the detector input impedance, which was high. Matching was, at best, crude since the primary coil of the tuner had only three taps. It also provided a small amount of selectivity since the ball and the inner coil of the instrument were self-resonant in the band around 400 meters, where most of the broadcast stations were located. When the variometer was added the selectivity was improved, since regeneration raised the grid impedance of the detector and because the increased sensitivity permitted the user to reduce the amount of coupling to the antenna. This receiver was capable of marginal loud speaker volume on local stations, using a long antenna, without the variometer. The regenerative version produced enough output on local stations to please the whole family.

In both of these sets, Atwater Kent provided an integrated unit, the TA detector-amplifier, that contained all the difficult connections. For several years subsequent to these sets, the same or very similar units, using exactly the same construction, were used on all AK radios. In retrospective evaluation, it is clear that these integrated units made a significant contribution to radio development, not so much from their electrical performance, which was no different from many other embodiments of the same circuitry, but from their mechanical character. Mr. Kent had very perceptively pioneered the use of steel shaping and phenolic casting to build convenient, effective radio instruments. The units were easy to manufacture and easy to use in assembling different radio receiver designs. They also gave the radios a distinctive appearance, which pleased Atwater Kent and provided the basis for eye-catching advertisements of the product line.
A third form of the TA unit, the two-stage audio amplifier, was used as the key instrument of the next receiver in the line and was introduced only one week later. This set is Part No. 3955. A companion set, No. 3960, came out at almost the same time (two days later). It is illustrated in Figure 7, which also shows the variometer that was added after purchase. The full configuration of No. 3960 is, from left to right: Coupled Circuit Tuner, Variometer, Single Tube Detector, and 2 Stage TA-AF Amplifier. No. 3955 was of the basic form of the No. 3960 but was sold with only the Coupled Circuit Tuner and the Single Tube Detector mounted on the board.

The single-tube detector unit was similar in size and form to the standard tube socket. It contained the filament rheostat but also included a grid-leak resistor and grid condenser. Its plate circuit was brought out on two posts, with the lower-potential post connected to a plate by-pass condenser. The two-tube amplifier looked almost identical in size and layout to the detector-amplifier unit used on No. 3925, but differed in having no detector circuitry, and having two audio transformers buried in the tar of the base. The input posts on the top deck were connected to the primary of the first transformer. The output of the second tube was brought out on other posts for connection to a loud speaker or to several pairs of earphones.

Apparently not all the customers that Atwater Kent sought to reach were interested in obtaining a complete radio in a single purchase. With the line of easy-to-add instruments that he had available, Kent could offer a one-tube, simple detector radio such as No. 3955 which the customer could upgrade in two steps, each representing a resale for the dealer. First, perhaps, the customer bought the variometer and had the benefit of a one-tube regenerator. Then he could have returned and bought the two-tube amplifier to complete No. 3960. He would then have enjoyed a radio equivalent to the regenerative detector-two stage sets generally available from many contemporary manufacturers. When the No. 3960 was current, Atwater Kent dealers and other outlets still carried the full line of radio instruments made by the factory so that upgrading was easy. Examination of contemporary radio sets built at home by radio fans using AK instruments reveals as many circuits and layouts as could be conceived, some of them of doubtful capability. It appears that the radio fan was encouraged by the Kent organization to experiment as well as to purchase factory-built receivers.

In the 3900 series of receivers, Atwater Kent manufactured one more set, No. 3975. It was very similar to No. 3960, as may be seen by comparing Figure 8 to the earlier pictures. The difference in the full configurations of these two sets was in the tuning instrument. The Variocoupler was used on the No. 3975 instead of the Coupled Circuit Tuner that was used on the earlier sets. The Variocoupler was made of a tapped stator inductance, inside of which was a rotor similar to those on the variometer and the coupled-circuit tuner. Together these inductors and their stray capacitances formed a tappable, tunable circuit resonant in the broadcast band, which at that time meant from a little more than 200 meters to a little more than 500 meters. The big advantage of the Variocoupler over the other instruments lay in the inductance taps.
The knob on the right, marked Coarse, permitted the user to select the number of turns he put in series with the antenna, six at a time. The left knob was for Fine selection at the rate of one turn per tap. By using these taps the operator changed the effective turns ratio between the antenna circuit and the grid circuit of the detector. This enabled maximizing the transfer of antenna energy to the detector (impedance matching). When this more effective matcher was used with the regeneration available by means of the owner-installed variometer, the set was the most effective member of the No. 3900 series for receiving weak stations. On stations strong enough to push the regenerative detector to maximum output, no advantage was gained from the matcher although volume could be controlled by mismatching.

The No. 3900 series was the only family of AK receivers that could be made to regenerate conveniently. Atwater Kent may have recognized that regenerators were destined to be replaced by more docile circuits, ones that didn’t require special experience to adjust properly, but so far no documentation indicating his attitude about regenerators has turned up. He may have been aware of the growing dissatisfaction in more densely populated neighborhoods with the tendency that regenerators had to operate in the lightly oscillating mode where they became annoying transmitters, tuned closely enough to the incoming signal frequency to produce program-destroying heterodynes in nearby receivers. It is easy to hypothesize that Kent, with his perceptiveness about what the customer would like best, and his sensitivity about his good name and the damage that could be done to it by the squealing, would try to avoid the problems of the regenerator. The next series of sets shows what he did, but doesn’t tell why.

**The 4000 Series**

The last few months of 1922 and the first part of 1923 must have been busy times in the Atwater Kent Manufacturing Co. They were still producing electrical system parts for automobiles and had initiated the successful line of
radio instruments. The engineering people must have worked on both the regenerators and the new radio amplifier configuration at the same time. The production department not only carried along radio instrument manufacturing but had to set up what was entirely new for the factory, receiver assembly lines. With the response from the dealers and distributors in handling the instrument line, the sales force probably made life hectic on Stenton Avenue, where the plant was located in Philadelphia.

Doubtless, in all this beehive of activity, Atwater Kent made his presence felt. From what is known of him through employees and his son, Mr. Kent took an active part in every phase of the business. He was active in the design, particularly in the mechanical side involving how the instruments appeared and how they were enclosed. He either closely supervised the layout of the assembly areas or did that job himself, since his admiration for Henry Ford’s work is well known. Kent’s insistance on quality was not relaxed in that period, either, since the artifacts show that appearance, function, fit and finish were maintained while new devices were brought on line.

The very end of 1922 saw production begin on five receivers in the 3900 series and then, in January 1923, the new line of radio sets was introduced. The first of these new open sets was No. 4052, shown in Figure 9. The new receiver was a four-tube set incorporating the detector-two stage audio amplifier unit that had been used earlier on No. 3945. To increase the amplification, a radio stage was included instead of offering a way to include regeneration. The radio amplifier was coupled to the detector by means of an iron-cored transformer shown to the immediate left of the three-tube unit.

Also added to the set was another new instrument, the potentiometer. It was wired across the filament circuit with its arm connected through the tuner to the grid of the radio amplifier. This instrument offered control of the radio stage amplification. The tuner was also new. Its purpose was to provide a resonator in the antenna-first grid circuit, where it made available very crude matching and some frequency selectivity. The tuner was designated Type 11.
was very similar, electrically, to the Variometer but looked different because the axis of the fixed coil had been turned from horizontal to vertical.

The interstage radio frequency transformer made possible a simple amplifier that was very similar to the standard audio amplifier used commonly in nearly all radios of the time. Because of the hundredfold increase in frequency, however, the unit was self-resonant. The transformer used in No. 4052 was marked "2" on its name plate. Another transformer marked "1" had been offered earlier as part of the original line of instruments. Apparently Kent and his engineers felt that the earlier transformer resonated too far below the narrow band of frequencies used by broadcasters in 1922, so the second one was designed to push its self-resonance to about 800 kHz. No. 4052 was not a high-performance receiver. With only the single fixed-tuned radio amplifier, its selectivity and its overall sensitivity were less than a well tuned three-tube regenerator, like the ones in the earlier series.

Radio engineers had found that the grid-leak detector followed by two transformer coupled audio amplifiers produced good output volume when the detector was operating with signals in the middle of its good-operating range. This was the basis of the AK three-tube unit and of the two-stage amplifier circuits offered by many other manufacturers, i.e., the RORK from Grebe and the 525 from Kennedy. Because more audio stages didn't solve the sensitivity problem, radio amplifiers (and regeneration) were investigated. One radio stage was not enough, even with a long antenna, for many radio listeners. Adding another stage was practical, although expensive, and that was the basis of No. 4066, the five-tube receiver shown in Figure 10.

Designing the AK open sets was not a difficult task. It consisted largely in putting together an attractive (to Mr. Kent) sample and making drawings of the new instruments and the assembly for the factory. The similarity of No. 4066 to its immediate predecessor makes this apparent. The electrical design of No. 4066 may have been a little more challenging, since using two of the radio transformers from the earlier set, No. 4052, would have resulted in oscillation.
of the two radio stages even with the gain reduced by the potentiometer. The
coupling in the tubes and between the transformers was too high for stable
operation. The solution to the problem was the use of the other transformer,
the early one available as a separate part, and marked "1". Because that one
was self-resonant at a lower frequency, moderately stable operation was ob-
tained using it in the output of the first stage, with "2" in the output of the
second.

A second effect was obtained although at the time of the set's introduction it
was not of great benefit. The radio was broader in its response band because of
the stagger tuning of the amplifiers. In early 1923 this resulted in more even
amplification of the two mainly used wavelengths. Unfortunately for Atwater
Kent's recovery of investment, the lack of frequency discrimination in No.
4066 resulted in almost instant obsolescence, when, in late 1923, the Radio
Commission reassigned station frequencies across the entire broadcast band.
The very limited selectivity produced by the Type 11 Tuner meant that stations
across the band came in almost equally well and the listener could do almost
nothing about the interference, except to install some kind of a wave trap.
Fixed-tuned radio amplifiers were a dead end, except for use in
superheterodynes, and Atwater Kent could not have licensed that circuit even
if he made that choice.

Three other open sets (not illustrated) were produced using fixed-tuned
radio amplifiers. The first, No. 4120, was based on the No. 4052. It used a
single tube detector instead of the three-tube unit. This was, therefore, a two
tube set that would have been attractive to someone who already owned a two
tube amplifier. The second set was based on the No. 4066, again substituting
the single tube detector for the three-tube unit. It was identified as No. 4275.
No. 4120 was introduced in March, 1923 and No. 4275 in June. The third set in
this related group was No. 4205, introduced in late April, 1923. It was a No.
4066 that used A-suffix tubes. Prior to No. 4205, all Atwater Kent designs
were based on the one-ampere filaments that were used in the 201 and 200
RCA type tubes. The new thoriated filament substantially increased emission,
permitting the tube designers to reduce the filament temperature and conse-
quently the filament current. The lower current tubes were given the A-suffix
and rated at one-quarter ampere. Lower current required increased filament
rheostat resistance and this led Atwater Kent engineers into modifying the
several tube units, assigning new part numbers to the new versions. The change
of the three-tube unit on No. 4066 therefore resulted in a change of the set
number to No. 4205.

There was another set in this group based on No. 4066 but it looked so dif-
ferent that a detailed analysis was required to establish the similarities. The set
was No. 4333, the first of the open sets to be alternately identified in the sales
literature by a model number. It was widely advertised as Model 5. Figure 11
illustrates the radio but does not make clear, except for the knob and tube
count, why this is a No. 4066. Model 5 production was started in September
1923. Electrically, Model 5 was identical to No. 4066 with one exception; the
radio amplifiers on Model 5 shared a common filament rheostat. Both sets
used Type 11 tuners in the antenna circuit and included two radio amplifiers with their iron-cored interstage transformers. The radio transformers in the Model 5 were suspended under the radio tube sockets using specially shaped bus wires.

The big difference between the two sets was in the use of a single drawn steel container to house all the parts that had been separately packaged in the No. 4066, as well as all the parts that were located in its three-tube unit. The construction of Model 5 represented the greatest degree of integration and size reduction achieved by Atwater Kent. It shows how much he was influenced by the potential use of shaped steel to provide an exo-skeleton that was attractive to the eye, easy to manufacture, and reasonable in cost. Other manufacturers such as Westinghouse and General Electric used shaped steel to enclose the catacomb that was the main part of the early RCA superheterodynes, but the result had the look of utility, not esthetic beauty. The point of beauty can be argued, but the acceptance of the open sets in their own times, and the enthusiasm of collectors in our time, testify to the visual effectiveness of Kent's taste.

The late introduction of Model 5 suggests that more engineering work than simple adaptation was required to complete its design. Working with the set, particularly checking the electrical performance, suggests that substantial modification was needed to make the set stable. The closeness of the radio tubes and their transformers must have caused an increased tendency to oscillate. Surviving Model 5 receivers have enough unwanted regeneration to make them oscillate when especially effective 201As are used in the radio
stages and the plate voltage is higher than about 45 volts. The set might well have turned into a bad sales problem if it had not been obsoleted by the need for selectivity. This resulted from the reassignment of frequencies by the Radio Commission at almost the same time as the Model 5 became available. Atwater Kent and his technical people must have been aware of the need for selectivity before the end of 1922, since another radio was being designed at the same time as the Model 5 and was introduced into production on the same day. It was Model 10.

Radiodyne and Model 10

Of the forces that came together so importantly for Atwater Kent, two have been discussed at some length in the descriptions of radios. They were the use of ductile steel to enclose the receiving instruments, and the manufacturing of radio sets by means of assembly line techniques. The latter force was more strongly felt as the number of radios produced per week increased beyond the craftsman stage, to the point where the operators performed only one or two related tasks on sets passing their work stations. The other two forces were not within Kent's direct control; rather they were the environment to which he responded. The first of these was the wave which carried the signal. Its characteristics influenced the circuits which he implemented, and determined the performance which he built into his receivers. The last force was the acceptance of the idea and of the importance of broadcasting by the general populace of the United States and Canada.

By the time that the 4000 series was obsoleted by the need to assign more than two wavelengths for general broadcasting (September, 1923) the count of licensed stations in those two countries had exceeded 550. The total number of receivers was well over one million. Of these Atwater Kent had sold only a very few (estimated as less than 25,000) but he recognized the market and what he had to do to substantially increase his share.

The selectivity requirement meant more tuned circuits. Overall receiver output was set by the listening public who wanted loudspeaker reception. Receiver input was determined by transmitter power and by the antennas used for transmission and reception. This required that the overall gain be at least ten thousand, and consequently made five stages necessary. Grid-leak detector limitations pointed directly to two radio amplifiers and two audio amplifiers. With the exception of the tuned circuits, this was the configuration of the unsatisfactory No. 4066. The next open set, No. 4340, added three tunable resonant circuits, fixed the problem, and started the run toward a million AK-made sets. That many were sold in the following four years. Atwater Kent more than recovered his investment in the electrical design that started with No. 4340, shown in Figure 12. The millionth set, a Model 35, had the same stage lineup and used the same tubes as that first three-dial receiver.

Two new instruments were developed for the No. 4340; a variable condenser and a radio transformer. The condenser carried the familiar hallmarks of Atwater Kent's mechanical designs, the deep drawn steel container and the beautifully cast Bakelite face and dial. The color of the containers was carried
over from the original line of instruments, a light green-khaki that the literature called gray. The transformer was a straightforward, single-layer solenoid that included a smaller hexagonal primary coil inside the cast Bakelite form. Both the condenser and the transformer used binding posts for connection into the rest of their circuits. Both also carried nameplates. Altogether the polished brass of the nameplates and the binding posts that set off the shiny Bakelite and the green paint, above the highly finished board, gave the set a very striking appearance. Compared to the dull rectangular boxes that were offered by some of the competition, the AK set had the real sales potential of strong visual appeal.

The name plates on the transformers tell an interesting story. They were marked along the lower edge (left side), with the word "Radiodyne". The introductory advertising material of the time used that name to identify the receiver, so it seems reasonable to assume that Atwater Kent had chosen the name for the new line. The trouble was that the Western Coil Co. of Racine, Wisc. had previously established their right to the name. No information has come to light about what must have happened around the factory when that piece of bad news hit Stenton Avenue, but only a little imagination is required to picture Mr. Kent's response since he was known to be an impatient perfectionist. While there is no direct evidence about what happened next, the story can be pieced together from the radios that have survived to the present. Quite a few green No. 4340 sets, with the same binding posts and nameplates similar to those on the Radiodyne, may be found in collections, but they differ in one important detail from the first set—the name plates on their transformers carry the legend "Model 10" in place of the word, Radiodyne. They are the No. 4340s that were produced after the Radiodyne name was discontinued and were referred to in the dealer and the public advertising as Model 10. From the time of their introduction, the No. 4340 open sets sold very well. Therefore, the pressure to change the nameplates must have been intense, and how intense is indicated by two other No. 4340 sets that have come to light. They tell what was done in the interim until the photo-etcher had the new
nameplates ready. The transformers on those two sets carried the same nameplates that were used on the single-tube sockets and on the potentiometer. They are marked “Atwater Kent, Phila., Patent Pending”. Production was carried on without a break while the transformers that had been finished were altered, and the succeeding lots assembled with the interim and then the Model 10 nameplates. The production rate approximated 1000 sets per week.

“Model 10” was used by the Atwater Kent Manufacturing Co. as a brand name for No. 4340. It was the first of a long line of radios that used model numbers as their names. While Models 5, 8, and 9 had lower numbers than Model 10, they were introduced later into production even though their designs may have been initiated before No. 4340. Model 10 was also used to identify the production radio in the factory even though the more customary method was to use the Part No. 4340. Neither of these nomenclatures was sufficient, however, to provide a unique identification, since many changes took place in the specific configuration of the No. 4340 receiver without causing a change in the numbers. One very obvious change was the color. In addition to the green set, a black crinkle radio was made. Perhaps the reason for not assigning new numbers was that the production rate had all but swamped the still growing facilities. Most of the changes that took place in the four months or so of Model 10 assembly were cost reductions that only made made minor alterations in the set’s appearance, and were not deemed worth implementing on such a short production run.

Some of the changes that were made to the Model 10 were: The binding posts on the condensers were eliminated, holes were pierced in the rear of the condenser enclosure for the wires that were connected under the board, the binding posts on the radio transformers were removed so that the coil wires went directly to the underboard wiring, and the binding posts on the radio tube sockets were eliminated in similar fashion. These changes seem to have been made all together, because so far no No. 4340 has turned up with some, but not all of the binding-post changes. Nevertheless, the changes resulted in four green and three black variations.
Another change that took place during the production of the Model 10 suggests that a new manufacturing facility was brought on line. The evidences for this conjecture are two; radio transformers with decorative rings cast into their tops were substituted for the earlier ones with the binding post bosses, and the general arrangement of the underboard wiring changed from a slightly curved form to a rigidly rectilinear pattern. With production rising, the molding machines and the assembly lines would have had to increase their rates. An upper limit would have been reached where all the available machine time was used in a process, such as curing the phenolic. When that happened more machines had to be put on line if the rate was to continue to climb, and the new machines and lines would have required additional space. This growth may have been accommodated by changing the Stenton Avenue buildings, earlier used for automotive-electrical manufacturing, to radio production. While no direct evidence exists to prove this conjecture, the reduction in advertising of the automotive line coincides roughhly with the Model 10 production period.

One more change took place during the manufacture of Model 10. The brown color that became familiar in later open sets and in the panels of the box sets was introduced. This time, however, the part number of the set was changed. The new set became No. 4600 but it was still a Model 10. It is shown in Figure 13. No. 4600 was equipped with the new style radio transformers and of course, had no binding posts on the condensers, coils and radio tube sockets. It was, however, the last of the Model 10 family to use binding posts for connecting the wires for A and B power.

**Models 10A, 10B, and 10C**

By the beginning of 1924, the market acceptance of the Model 10 open set proved that Atwater Kent had entered the market with the right product. The next tasks for the factory were further expansion of production, and the introduction of new features that would assure continuing sales growth. During
the year a new plant that was large enough for growth far beyond the open sets was built on Wissachickon Avenue in Germantown.

Improvement of the radios was accomplished by continuing the changes that started with the removal of the binding posts on Model 10. The next change was to add a power cord to the set, making it far more convenient to connect the batteries needed for its operation. It resulted not only in assigning a new part number, but also in adding a suffix letter to the model number. The changed set was No. 4550 if colored brown, and No. 4560 for black. Receivers of either color were called Model 10A. A brown Model 10A is shown in Figure 14. On the illustrated set the binding post bosses may be seen on the radio transformers, but other sets came from the factory with the decorative rings on the coil forms. This suggests that the two facilities conjectured for Model 10 production continued to assemble open sets.

The practice of making minor appearance alterations without changing the identification numbers continued. Such variations included eliminating the nameplates from the condensers and the coil forms, and removing the separate ground connection binding-post on the left edge of the board. The number of variations of Model 10A that could be found in present-day collections approaches sixteen when color, bosses, nameplates and ground are reckoned.

The tendency for the radio amplifier section of three-dial radios to regenerate was closely related to several factors; tube amplification, interelectrode capacity, and inter-coil geometry. Hazeltine developed and licensed a way of securing control of the latter two factors, but Atwater Kent preferred to go his own way. He rotated the transformers to orthogonal positions for the next set in the product line, Model 10B, shown in Figure 15. This change reduced the magnetic coupling between transformers but did nothing about the capacity coupling in the tubes. The set was still difficult to use when its greatest sensitivity was desired.

The popularity of the three-dialer came, not so much from its small signal performance, as its easy use by a family listening to the broad range of pro-
grams being offered by the highly competitive broadcasters. The Model 10B was probably an improvement over the Model 10A, but comparisons made on surviving sets do not show a clear difference. The Model 10B was offered in the same colors as the earlier sets, black and brown. The black set was still identified as No. 4560, and the brown one as No. 4550. Models 10A and 10B were introduced early in 1924, but were produced for only a little more than half a year, when they were replaced by Model 10C. The production rate by this time had reached almost 5000 sets per month.

Another circuit improvement made the difference between earlier sets and the Model 10C, pictured in Figure 16. Damping resistors were added to the grid circuits of the radio amplifiers to make them less liable to regeneration. Neutralization might have been better but apparently Atwater Kent did not receive enough negative customer response to justify adding that feature. The damping circuits in Model 10C were carried forward for more than three years, even after Type 26 tubes replaced the 201As and the sets became house-powered metal boxes.

Changing the grid circuits permitted the deletion of the potentiometer on the open sets. The cost reduction was worthwhile, but another benefit was available. Without the pot, the spacing between the first and second tuning condensers could be reduced. A change to the filament circuit to eliminate the rheostat in the second tube socket permitted reduced spacing between the second and third condensers. The radio in Figure 16 is the standard Model 10C, part No. 4700, which was two inches less in width than Models 10A and 10B.

Another version of Model 10C, illustrated in Figure 17, and also identified as No. 4700, was brought out, probably late in 1924. It was further reduced in width by about 3½ inches, simply by locating the instruments closer to each other. The main identifying feature of that set, aside from the width, was the lack of end boards. It used strips that were rabbeted into the contoured ends of the main board instead of the full-thickness cross boards used on all other open sets. In late 1924 and early 1925, about forty thousand Model 10C receivers were produced and sold.
Listeners who lived near higher-power local stations did not need two radio amplifiers on their receivers. For them, Atwater Kent produced four-tube receivers that started with No. 4052, but differed from that set by using a tunable radio amplifier in place of the fixed-tuned stage. The first of these tunable sets was introduced into production at the same time as the Model 10, September, 1923. It was identified as No. 4445, and then when model numbers came into use, called Model 9. Figure 18 shows the set.

The instrument in the middle was a Coupled Circuit Tuner, similar to the instrument that was offered separately for set constructors. It was a self-resonant tunable transformer made up of three coils; a rotor identical to that in the Type 11 tuner, a closely coupled spherical coil with which the rotor resonated, and an outer coil that acted as the primary of the transformer. The Model 9 receiver was a compromise between selectivity and price that must have been popular, because as the Model 10 sets developed, the Model 9s followed a similar course.

The illustrated Model 9 used binding posts for power and was painted green. Its immediate successor, not illustrated, used a cable for power and was painted brown. Then at the time of the Model 10C a different configuration of the four-tube radio was introduced. It was identified as Model 9C, No. 4660, and is shown in Figure 19. The Model 9C was, from both circuit and mechanical standpoints, almost exactly a Model 10C with the middle stage removed. It was painted brown and used a cable for its power connections. In the same way that Model 10C was the predecessor of Model 20, the Model 9C preceded the Model 19.

Among Atwater Kent open sets, the Model 10 series seems to provide the basis for portraying the development of the entire product line. Model 9 could
very easily be considered as a simplification of the technology of Model 10. Model 12 could be treated as an extension. The difference between any Model 12 and its Model 10 counterpart was in the number of audio amplifiers and how they were packaged. The development work for this variation was done at the time the individual instruments were the product line, before the production of radio sets began. Only application and assembly work was required to manufacture the Model 12. The last of the six-tube open sets, Model 12C, No. 4910, is shown in Figure 20. Clearly the radio section was that of the Model 10C, even to the placement of the coils and the switch. The difference is in the use of the Detector-One Stage Amplifier and the Two Stage Amplifier instead of the three-tube unit on the Model 10C. In recognizing this set, the key points were the small tube socket for the second radio amplifier and the stage-disable switch on the second two-tube unit.

Corresponding to the Model 10B receiver, Atwater Kent produced a six-tube set, usually referred to as a Model 12B, No. 4620, although there is no clear documentary basis for the suffix letter. The set, not illustrated, used the radio section from the Model 10B and the two-tube units that functioned like those on the Model 12C, except for the stage-switch which hadn't been included.

From performance measurements made on the Model 12 series, the inclusion of the switch on the Model 12C was more than a power saving improvement. On moderate to strong signals, the use of the last stage produced so much distortion that other steps, such as reducing filament temperatures to the starvation level, had to be taken. For the listener who was especially interested in distance listening, however, the Model 12 was the best choice.

A third Model 12 style, a six-tube set, was produced when the five-tube Radiodyne was introduced (and withdrawn). Like the later ones, this six-tube receiver used the same radio section as the corresponding Model 10, in this case the Radiodyne, even to the nameplates on the transformers. No mention of this radio as a Model 12 has been found in the literature. One of these sets has survived and it is identified by its tags as No. 4375. It is not illustrated. The
two-tube units on that set were identical to those used in the 3900 series of receivers even to the color, green. No example of a model corresponding to the first Model 10 (changed nameplates) or its variations has turned up.

**Conclusion**

In producing and selling more than 120,000 open sets, Atwater Kent demonstrated how an entrepreneur can combine the offerings of a new technology, his own capability and the needs of a society to initiate changes that endure far beyond the times in which they were made. In many ways he was an explorer, and like many other pioneers, he was driven by internal forces that left neither time nor opportunity to see the effects that his work would leave. This is the task of the collector/historian.

Production of the open sets led to an efficient factory, and broadcasting led to a new way of life. Atwater Kent continued in the radio business, producing ever more radio sets and becoming an active user of broadcasting’s power and influence. The story of the wooden box receivers and of the metal box radios that followed iterates and strongly emphasizes the contributions that Arthur
Atwater Kent made to a new way of life. His story can be told many times with different faces, different needs and different artifacts, but his example will be long remembered.

Fig. 1. The Empire State Building in 1934. The two vertical dipoles at the top were originally for the sound and picture signals of the 120-line television tests. One of these was used for the Armstrong FM field tests.
FIELD TEST OF THE ARMSTRONG WIDE-BAND FREQUENCY MODULATION SYSTEM FROM THE EMPIRE STATE BUILDING, 1934 AND 1935

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Editor's Note: The following paper is written from the unique vantage point of an engineer who worked closely with Major E.H. Armstrong on the early development of frequency modulation (FM), as an aural broadcasting service. Some qualities of Howard Armstrong as an engineer, inventor and human being are disclosed, not often found in print. His system of frequency modulation was in some respects a contradiction of accepted theory in that it achieved a reduction in noise level by using a channel having greater rather than smaller bandwidth. Armstrong was inclined frequently to say that one of the difficulties in what he was doing was that people so often knew so many things that weren't so. The development of Armstrong's system of FM stimulated work on information theory which provided a better understanding of fundamental communications principles which, in turn, has guided the design of today's complex systems.

R.M.M.

Much has been written about Edwin Howard Armstrong and his four major contributions to the Radio Art. It is remarkable that nearly sixty years after his first disclosure, all four inventions are still in use. Frequency modulation as applied to aural broadcasting is in fact still developing in its service to the public. The last decade has seen an accelerating use of this method of broadcasting, with the advent of stereo and the increasing use of FM in cars providing some of the impetus. One might wonder how the Major would react to some of the sounds now heard on high-fidelity FM. The aural channel of the TV service has used FM throughout its commercial life.

Little has been recorded, however, of the first full scale FM field test conducted by Major Armstrong at the NBC transmitting plant at the Empire State Building. It was my privilege to work with this man and to benefit from the expertise which he brought to bear on problems as they arose.

The National Broadcasting Company first occupied space on the 85th floor of the newly completed but sparsely occupied Empire State Building in September, 1931. An experimental television station was constructed to conduct tests on VHF using 120 line scanning with photocells for transmission. Cathode ray tubes called kinescopes were used for picture reproduction, replacing the earlier technique in which a neon plate lamp was viewed through a scanning disc. The early kinescopes employed a willemite phosphor which
Fig. 2. Armstrong frequency modulation exciter equipment, used in the 1934-35 field tests, at the Empire State Building. The breadboard unit in the rear, just to the right of the microphone, was exhibited at a Canandaigua conference.

Fig. 3. Transmitter at W2XDG used in the FM field tests. This view shows the 831's in the tripler and intermediate power amplifier.
provided a picture in various shades of green. Perhaps some will recall seeing the green light in an otherwise darkened house during much of the early black and white TV era. The Empire State plant provided facilities for originating live and film picture signals with accompanying sound. The picture transmitter was licensed as W2XF to operate on 44 mc, and the aural transmitter as W2XK on 61 mc. Separate antennas were provided in the form of vertical dipoles extending above the five inch coaxial lines, and the transition from transmission line to antenna occurred at approximately ten feet above the top of the Empire State Building.

Extensive tests of this system of television transmission were conducted during 1932 and 1933. Although these tests proved the feasibility of using VHF for broadcasting, they also established that further substantial improvement in the quality of television picture transmission would be required before serious thought could be given to the development of a television broadcasting service. In the vernacular of the time, “Television was still just around the corner.”

During this same period, Major Armstrong had been working on the development of wide-band frequency modulation at Columbia University. By the end of 1933 he had satisfactorily concluded initial tests of his method of wide-band FM telephony and had been issued four patents. At about this time he apparently met with David Sarnoff for the purpose of informing him of the new development, and may also have given him a demonstration at the Columbia laboratory. Probably as a result of this meeting, the NBC transmitting facility at the Empire State Building was made available to Armstrong to permit a full scale test of the new FM system.

The first visit of Major Armstrong to the Empire State Building transmitting facility is noted in a record of visitors which was maintained at that time. Under date of January 12, 1934, we find the following entry: “Mr. Beverage of RCA Communications and Major Armstrong here to discuss some experimental work which Major Armstrong expects to do here in the near future.” This visit was promptly followed by another on January 19, 1934. The notation indicates that Major Armstrong was there “to get information on W2XF for experimental work he is to do on it in near future”. W2XF was the visual transmitter used in the 120 line television tests.

The power amplifier for W2XF consisted of two 846 water cooled neutralized tubes operated in push-pull at approximately 5 kW input power. Measurement of radio-frequency power in this portion of the spectrum - with believable results - was still in the future. Based on the difference between the loaded and unloaded resonant current drawn by the P.A., we believed the carrier output power was approximately 2 kW. The I.P.A. and the tripler used the 831 air-cooled triode (WL-674 and FP-2 were the Westinghouse and G.E. designations of comparable tubes). The 860 screen grid tube operating as a push-pull amplifier drove the high power tripler. The overall frequency multiplication in the transmitter proper was 24 times, provided by three doublers and one tripler.

During February, 1934 the TV test transmission schedules were changed at
Armstrong's request. Network programming was applied as amplitude modulation on W2XF in place of tone or picture signals. This portion of the test was probably directed to field observations on the coverage which might be expected of this transmitter. On March 26, measurements of the band width of the radio-frequency multipliers and amplifiers as well as the band width of the antenna system were initiated by Armstrong. Observations at both the transmitting plant and at the Columbia laboratory were correlated. It is now evident that the purpose of those measurements and observations was to assure that the FM signal could pass through the transmission system without distortion. The Major had long since learned to take nothing for granted.

This meticulous approach uncovered several problems which were dealt with in due course. The antenna system offered a serious mismatch to the coaxial line, thus restricting the effective bandwidth of the antenna system. The radiofrequency stages in the transmitter were designed for maximum efficiency, since in the design application no bandwidth requirements were imposed on the driver stages. Both of these problems were effectively resolved with assistance from P.S. Carter on the matching problem and John Evans on the circuit problems.

During May, 1934, Major Armstrong had FM exciter equipment suitable for driving the low power stages of the transmitter moved into the television studio space on the 85th floor, adjacent to the transmitter. Test and adjustment of this equipment was started at once. Also in May of 1934 NBC received an experimental license which had been requested to cover experimental operation of the television picture transmitter on frequency modulation. W2XDG was assigned to operate on 40.6 and/or 41.0 mc for this purpose. A field intensity survey by RCA Victor engineers was promptly conducted at Armstrong's request.

The FM tests from W2XDG started on June 2, 1934 on 41 mc; the total time of operation during June was 49 hours. The antenna transmission line matching project was completed on June 6, and on the evening of June 20, 1934, a special demonstration of organ music was transmitted for observation by General James G. Harbord, the then-Chairman of the Board of RCA.

The FM exciter equipment as set up in the shielded TV studio was composed of a number of classical "breadboard" units. This type of construction provided adequate performance and excellent access but it obviously did not conserve space.

It should be noted here that while standards of operation and adjustment were established and maintained by the Major, the responsibility for operation in accordance with the terms of the license was in the hands of the NBC technical staff. This meant that close relations and cooperation had to, and did in fact, exist between the Major and the NBC engineers. Telephone communication was frequently employed between the point of observation, for example Harry Sadenwater's home at Haddonfield, N.J., and the transmitter plant to permit optimum interchange of information. Thus the mode of transmission or the nature of the modulating signal could be in full accord.
with the Major’s requirements. Similarly, when discrepancies appeared, the cause could be quickly isolated and corrections applied.

Tests continued through July with facsimile signals being added for test transmission to Haddenfield. However, trouble developed on July 30, 1934. The large insulator which supported the upper section of the center conductor of the coaxial line as well as the antenna rod for W2XDG/W2XF had failed. Initially the failure was believed to have been caused by lightning, which hit the antenna frequently. Repair of the initial failure was effected promptly by removing the antenna and replacing the insulator with an identical spare.

When the antenna rod was removed a substantial number of pit marks were discovered. These were tracks left by lightning. The fact that the two experimental TV antennas were the highest points in New York City and were frequently struck by lightning made them of much interest to K.B. McEachron of the G.E. High Voltage Laboratory at Pittsfield, Mass.

Arrangements had been made a year prior to the Armstrong tests to permit the installation of current and voltage measuring devices to gather information on lightning stroke phenomena. There were approximately 180 pock marks in the top 18 inches of the two inch diameter rod. Since the rod had been in service for three years, this suggested the occurrence of approximately 60 strokes per year. McEachron acquired the original rod and, judging from marks made in the same material in the lightning laboratory, stated that some of the strokes achieved a peak current on the order of 100,000 amperes.

A second antenna insulator failure of the same type during September led to the conclusion that the failure was caused by excessive heating due to the poor dielectric characteristics of the porcelain material at VHF. Action was then initiated to have a special insulator manufactured, and Steatite, a material having a much superior high-frequency characteristic, was specified. Since delivery of such a custom made insulator was estimated to be 6 months, RCA Communications prepared a temporary replacement made of rings of Mycalex. A coaxial line test set-up was prepared for testing these insulators at 41 mc, and as a result of this test the superiority of Mycalex over porcelain in this application was clearly demonstrated.

W2XDG was returned to service on October 10 with substantially increased radiated power, attributable to the reduction of loss in the temporary Mycalex replacement insulator. During October Armstrong commenced multiplex program tests in which two separate programs were simultaneously transmitted and successfully received at Haddonfield. These tests continued into November, 1934 with four simultaneously transmitted channels comprising program, facsimile, synchronizing for facsimile, and telegraph.

When Major Armstrong planned to make adjustments to or measurements on the performance of the FM signal generating system, he would usually phone in the morning to advise that he would arrive after lunch, meaning some time between 2 and 3 PM. After a few words of greeting and an outline of projected demonstrations, the Major would shed his jacket and frequently his shirt and tie as well, and proceed with his work in the studio. He was
sometimes unduly secretive about his objective or the nature of the problem he was trying to solve. Time meant nothing to him. The 5 PM quitting hour would come and go but Howard would continue to tinker. However, when an acceptable stopping place was reached, he would confess to the need of some nourishment and more often than not would take all hands out to dinner before turning us loose. Those were memorable occasions during which incidents in the early history of radio would be colorfully related.

We sometimes wondered about the Armstrong lunch. When Howard appeared at Empire State after lunch he was obviously full of vim, vigor, and vitality. Harry Houck recently related a story which sheds some light in this area. It seems that Tom Styles frequently accompanied the Major at lunch when the center of activity for the day was at the Columbia laboratory. One day the lunch counter which they usually frequented was closed. Tom, always eager for a good meal, induced the Major to try a nearby French restaurant. After carefully studying the exotic fare offered, Tom ordered frogs legs provinciale. When the waitress addressed the Major he ordered a cheese sandwich and a glass of milk. Tom remonstrated, saying, “Look, Howard, you always order a cheese sandwich and a glass of milk. Let’s make this a little special occasion”. The Major regarded Tom quizzically, passed his hand over his bald pate, and said, “Tom, you’re right. We should make it a special occasion. Waitress, make that two cheese sandwiches and two glasses of milk”.

During important demonstrations of the system Armstrong would arrange to have Jack Shaunessey be with us, just in case of some unforeseen problem with the FM equipment. On one occasion consternation arose when, in making a periodic routine test of the system, no signal emanated from the FM generating equipment. It was Jack who asked the 64-dollar question, “Did anyone charge the storage batteries?” A new set of batteries complete with spares and a charger assured the end of that problem.

It might be appropriate at this point to describe the receiving setup in Haddonfield, N.J. where Armstrong gave many demonstrations during these tests. Harry Sadewartner of the RCA staff, who was also a member of the Radio Club of America and a long time friend of Howard Armstrong, lived in a nicely situated home with an ample back yard in Haddonfield. This site, approximately 80 miles from the Empire State Building, was an almost ideal spot, from the Major’s point of view, to demonstrate the superiority of FM over AM broadcast reception from New York.

The receiver comprised several radio cabinets containing the intermediate-frequency amplifiers, the limiters, the discriminator, and the audio amplifiers. These were preceded by a high-frequency converter consisting of a modified RCA Communications high-frequency receiver. The units were set up in the Sadewartner rumpus room in the basement, hampering the intended use of the bar for many months. The antenna was carefully chosen since it consisted of a vertically polarized half rhombic. The center was supported by a 60 foot vertical mast and the antenna was, of course, oriented toward New York. The rhombic was later supplemented by a vertical dipole mounted on the side of the house.
In order to insure our involvement and cooperation, the major entertained those responsible for the operation of the Empire State facility and ran a special demonstration for us at Harry Sadenwater's home in Haddonfield.

In December, 1934 steps were taken by NBC to re-equalize the two program circuits from Radio City to Empire State. These circuits had been equalized to 10 kc, but new equalizers were prepared to bring the response flat within 1 db from 30 cps to 14 kc. This was undoubtedly part of Armstrong's plan to establish and demonstrate FM as a very high fidelity system. Radio City, with its new studios and equipment, had uniform frequency response to at least 15 kc.

Early in 1935 activity centering on the Empire State transmitting facility grew to a crescendo. In addition to the Armstrong tests, RCA was studying propagation characteristics of the FM frequencies as well as other portions of the spectrum, and preliminary comparative tests of AM vs narrow-band FM vs wide-band FM were conducted concurrently with tests and demonstrations by the Major.

On May 7, 1935, at the annual stockholders meeting of RCA, David Sarnoff announced development of a much improved system of electronic television, and plans to start field tests in less than 15 months. This meant that conversion of the Empire State transmitting equipment would have to start very soon. It also meant that the use of the transmitter by Major Armstrong for FM tests would have to be terminated. Plans for completely rebuilding the antenna and transmitter plant were being developed under forced draft and personnel unfamiliar with the plant were being trained to operate the existing facility and make the planned modifications.

During June, July, and August of 1935 final improvements in the FM equipment were made and tested. Further demonstrations were given, with reception usually at Haddonfield. The Major was quite fond of comparing FM reception on VHF with that of the 50 kW WEAF transmitter on Long Island on a warm August afternoon when there was a nearby thunder storm. Reception of WEAF was, of course, badly marred by the heavy static, whereas the FM reception from W2XDG was crystal clear.

In October, 1935 the aural transmitter rebuilding had been in progress for more than two months and the parts for the modification of the visual transmitter were on hand. With Armstrong's reluctant permission, the FM equipment in the studio was dismantled so that the studio area could be used for some of the required construction work. Thus the FM field tests by Armstrong at the Empire State Building were terminated.

It should be apparent from the foregoing that much was learned during the course of the FM tests that is now taken for granted as an established part of the radio art. The importance of antenna impedance matching to the transmission line and of using low-loss insulators at high frequency, the necessity of designing antennas so that points of mechanical support are not at high-voltage points, to say nothing of transmitter considerations, were well learned during the FM field testing. It is interesting to note that two years later, when
the Major decided to build his own FM station at Alpine, he ordered a high-powered transmitter from RCA.

After the death of Armstrong early in 1954, it became necessary to dispose of the large collection of equipment and material which he had accumulated over the years. This included electronic gear involved in all of his inventions and developments, from his regenerative receiver and the first superheterodyne to and including the FM equipment used in his many tests and experiments. This equipment was stored at his old home in Yonkers and at Columbia University.

It fell to Armstrong’s long time friend and associate, Harry Houck, to rescue this material from the junk man and oblivion. It was trucked to a large red barn in northern New Jersey, where it was stored for many years. A few pieces of breadboard equipment have been identified as those used in the Empire State tests. It is Harry Houck’s intention to identify, preserve and suitably display those pieces of equipment which constitute a significant part of the Armstrong story.

I hope it is evident, but perhaps it should be stated, that I considered it an exceptional privilege to have had the opportunity to be so closely associated with Major Howard Armstrong during the development of FM, and to have had the opportunity of observing perhaps the world’s greatest development engineer at work.

*Photos courtesy of R.M. Morris*
AN INTERVIEW WITH PAUL GODLEY

By Wayne M. Nelson, W4AA

This interview was a part of the program at the Antique Wireless Association Historical Radio Conference, Sept. 25, 1971 at Canandaigua, New York. The interviewer was Wayne M. Nelson, W4AA. This paper was transcribed by John A. Bryant, W4UX, from a tape recording made by Louise Ramsey Moreau, W3WRE.

NELSON: Paul Godley is a Fellow of the Radio Club of America and a past president, a Fellow of the Institute of Radio Engineers, now Institute of Electrical and Electronics Engineers, and a founding member of the Association of FCC Consulting Engineers. He was recognized and honored with a bronze plaque by the Executive Council of the Second Radio District. The American Radio Relay League, also in 1930, made a Sheepskin Award and in 1958 made a Merit Award. The Radio Club of America, in 1950, presented him the Armstrong Medallion. The Veteran Wireless Operators Association in 1935 gave him the Marconi Memorial Award and again in 1965 the de Forest Audion

Award. Broadcasting Magazine in 1946 ran a feature story about him titled “Our Respects to...”

Paul, you have lived a life that has been very, very rewarding and we have had a great time looking on you as a legend and a tradition over all these years. You have taken time from amateur work to engage busily in broadcasting and you have taken time from broadcast engineering to still be a good ham. Since the principal thing about our meeting today is the fifty years — or will be in December — since the first message spanned the Atlantic on short waves, I would like to ask you about the rather bleak temperature over in Scotland when you received the signals from America, 1BCG. Won’t you fill in some of the things the fellows have wondered about?

GODLEY: Well, I liked the temperature on the site of that test work in Scotland last May and June. In December of 1921 it was rather miserable and difficult. I suppose most of the people here have read the story of those Transatlantic tests, and one thing I suppose most of them haven’t fully appreciated is the fact that the checking operator assigned to me for those tests — a commercial operator of the British Marconi Company, by no means a ham — was interested in helping to the point that he went through the same difficulties that I did - mud, water, high winds and cold. But I was the only one who really suffered from it, in that I caught a very heavy cold. According to him it was because I didn’t drink enough Scottish liquor. It was a tough situation — however, something that no amateur would have worried about in the circumstances. The thing was to try to go through and accomplish something. That was the driving force and from out of that seemingly came all the energy necessary to cope with the weather, the hard work that had to be done and the lack of sleep throughout the period.

NELSON: Paul, you have been a legend to all of hamdom over the years. The hams probably do not know as much about your professional activities — some of that is really news to some of the hams. The work you have done is something we would like you to tell us even a bit more about. Won’t you feel free to digress from one point to another as you will, please?

GODLEY: Something I think none of the hams has known is that the roots of what was done in Scotland were really planted many years before, which is rather a long story.

As a very small child in Western Kansas, later Missouri and then central Iowa, I heard a very great deal, almost constantly, from the elderly people in these communities, some of whom had been on wagon trains crossing the continent, about the terrific impact which the transcontinental railroad and its essential Morse telegraph had had and was having on a burgeoning nation, a nation which now was tied together from coast to coast. When we got to central Iowa, so that my brother, who was twelve years my senior, could go to college, he shortly set up a telegraph line between our home and that of the son of a doctor who was a classmate of his. That fascinated me, and upon finding my interest, my brother began to tutor me in the basic electromagnetic laws and long before I was old enough to go to school I was learning and reading the Morse code and mastering the telegraph.
My father was an ordained minister of the Protestant church and an educator. My mother was also an educator. She was an artist and taught in two colleges. Consequently, our weekend guests and dinner guests regularly consisted of educators, church people and oftentimes foreign missionaries. I think when I first heard the rumor of the boy in Italy who thought he had a wireless telegraph, or telegraph without wires, a rather amorphous dream began to form in a very small boy’s head about the possibility that some day, without wires, the whole world could be tied together and from which there could come general understanding between all of the disparate peoples in the world with their differing ideologies and tongues; and that out of that the whole world might be bound together and we could come to understand each other, after which there might sometime be complete amity and world peace.

I bring in this early part because, due to circumstances beyond control, I was thrown on my own at the age of fourteen for actual survival and for such advanced education as might be essential to the boyhood dream. There again, Mr. Morse came into the picture, because I financed my college and university education with Morse, working on the railroads and with the various commercial telegraph companies, press wire services and so forth, which made it very easy.

Then, at the University of Illinois, Dr. Berg, who was an eminent educator and had long been a close associate and at one time a roommate of the eminent Steinmetz of General Electric Company (and I had gone to the U of I after college because of Berg) told me to my deep disappointment: “Paul, nothing of consequence can happen in the wireless field during your lifetime. Forget it. The place for you to work is in the transmission of electric power at high voltages across long distances.” That discouraged me deeply. Even so, I clung to the dream.

Trouble With The Long Waves

I taught school the following year. Two years later I was on the equator, up and down the Amazon River basin, putting together a chain of wireless stations for connection with Bolivia and Peru, so that there might be the first transcontinental communication across South America. And there I got a double dose of static, like the commercial companies of Europe and the States at that time, who had great difficulty getting traffic dependably across the Atlantic. In Brazil we could work successfully and handle traffic but about five hours a day on the average — between an hour or hour and a half after sunrise to eleven or eleven thirty or twelve o’clock noon. Then it was useless. You just had to shut down.

But in 1909, while I was working on the Great Lakes as installation engineer for United Wireless Telegraph Company, I had met Dr. Lee de Forest and acquired at that time two of his vacuum tubes. I think I agree that Dr. de Forest, notwithstanding that he was a graduate of Yale’s Sheffield Scientific School, was not in fact a scientist. (He, too, interestingly enough, was the son of a minister.) As I studied and thought in Brazil, I related those vacuum tubes to my boyhood dream. I can see that I thought then; without any question in my
mind, that transoceanic telegraphy could never be a success as long as it was on long waves and had to deal with this static. I concluded that when I got back to the States, after finishing my two-year go in Brazil, I would take my savings, which had been banked for me in New York in gold while I was down there, and do a little independent research work.

**Godley Meets Armstrong**

In almost a matter of days after I got back to New York I was taken as a guest to a meeting of the Radio Club of America and asked there to tell something of my experiences in Brazil, which were rugged. They were comparable, although the temperatures were vastly different, to what I went through across a short period in Scotland many years later. At this Radio Club meeting, after I had finished my talk, a tall fellow got up in the back of the room and said: “This is all very interesting,” because he had heard one of the stations, a station that signed “MS.” But he never could learn where it was because they always were talking a foreign language, in the radio code, which was Portugese. This surprised me. After the meeting I asked him where he lived, what sort of a rig he had. Well, he was at his home in Yonkers, New York, and he had a small antenna. I suspected strongly that this fellow was giving me a lie. Anyway, I asked if I might see his set-up and he told me he didn’t know, he would have to see his patent attorneys. I thought that was a brush-off.

Nevertheless, ten days later Armstrong called me on the phone and told me that if I would agree to sign a statement to the effect that what he showed me was new to me, his patent attorneys had said I might see it. And I did see it. I saw a demonstration. I knew at once what was involved — regeneration — but it was a new concept to me. My first question of Armstrong was what he had done with this on short waves because, abandoning the long waves in my own mind, I thought if I can’t come up with something on the shorter waves I am going to forget the whole business and go back to work for the wire line companies, telephone and telegraph, and have no difficulty making a living, and so on, but I had to get this out of my system. He said: “I haven’t been able to get it to operate below about a thousand meters because of the characteristics inherent in the vacuum tubes I have been able to get, and moreover, I am only interested in the commercial application.” I said nothing. However, here was a challenge and within a matter of days I had Armstrong’s regenerative circuit in operation, demonstrated it to him, and out of this came the Paragon receiver.

**The Old Paragon Line**

NELSON: Paul, right here are some of the Paragon catalogs. Does this bring back any recollection of former activity to you?

GODLEY: Well, it should, because I wrote every word of it. It brings back many recollections. Of course, by the time I had developed this regenerative circuit for short waves it occurred to me at once that it was applicable to amateur work and might be a boon to amateurs and therefore I ought to get into manufacturing. Moreover, all my money by now was spent and I had to recoup, so I borrowed $5,000, bought into the partnership of the Adams-
This advertisement for the receiver designed by Paul Godley was in *Radio News*, April-May, 1922.

Morgan Company, which had been predominantly a purely mail-order house, developing the Paragon line of equipment made of the company a radio manufacturer, I suppose I might say.

During that period, too, I first met Hiram Percy Maxim and a great many of the other early amateurs because I had to look to the amateurs as customers for the products.

NELSON: Here in *Radio News* (incidentally the only issue Mr. Gernsback ever had to double up on, April and May, 1922) is an Adams-Morgan Company Paragon advertisement; it reads: "1915 First regenerative receiver ever manufactured bore the name Paragon," and then this: "1916 First transcontinental amateur radio reception (California from New York; not prearranged) was effected with a Paragon Type RA-6 receiver." So, there are the first things your brainchild accomplished.

GODLEY: Yes, and I always liked this heavier-typed line here: "There's a good reason."

NELSON: A good promotion. There are a number of other things: I notice in the Radio Trade Directory here, 1924, you have the book-edge: "The new Paragon line, see page 2." Somebody was a good promoter in the Adams-Morgan Company, wasn't he?

GODLEY: Well, I'll take your word for it.
How The Handbook Got Started

NELSON: There is another thing that comes to mind.

We were talking at some length about the ARRL Radio Amateur’s Handbook. Would you like to touch on that particular point right there — your participation in this, or instigation, shall we say?

GODLEY: Well, this came about unexpectedly. The League had a convention in St. Louis following World War I. I attended and unbeknownst to me, on the way home by train, here was Hiran Percy Maxim. When he spotted me he said: “Oh, Paul, I must talk with you.” We sat down and talked at great length. Prior to the war, Clarence Tuska had been doing all the work for the League, editorial and otherwise, while Maxim was paying the freight — financing it. Maxim’s initial concern as we talked about the future of the League was that he could no longer carry that financial burden and he didn’t know what to do, whether to start up the League again or how it could be started, and so on. He was rather despondent about the whole thing.

I suppose subconsciously, at least, for selfish reasons, I felt that the League should continue because we needed customers, and I told Maxim that in my mind the League had to be gotten going again; that he could not depend in the future on an unpaid staff at headquarters, if there were to be a headquarters; that QST would have to be published; that furthermore, the way to get this thing rolling was to approach a number of the prominent amateurs in the East. I knew many of them would be willing to lend the League, or make a gift to the potential new League, of a thousand dollars or so each and in that manner there should be enough funds to get rolling again. Moreover, I said, if you are going to do the job that should be done, because there is so much general ignorance amongst the amateurs over the country, there has to be some kind of a bible for the amateur, a handbook.

Actually, as it came about, Maxim got together with a board of directors that he appointed and the money was raised. I was designated to write the handbook with the help of a high-school teacher in Muncie, Indiana, whose name at the instant escapes me. I did write an outline for the handbook, but I wrote Maxim and told him that inasmuch as I was a manufacturer, and would be wanting to advertise in the handbook and in the ARRL magazine, I felt that it was just impracticable for me to come up as author of the handbook because our competitors would squawk like hell. Maxim finally accepted that, but at that time they insisted that I continue as, I think the title was, “Technical Advisor” or something of that sort, for the League and I think I held that position for a couple of years.

It was some time before a handbook came out. Finally, Handy brought out the first edition which later was called “Handy’s Handy Handbook,” which I always felt was wrong. Of course there is nice alliteration there, but I felt nobody’s name should be on the handbook because inevitably in due course there would be a great many contributors to the handbook if a thing of biblical nature, so to speak, were to come up. But I have always taken deep satisfaction from the fact that I feel the League perhaps was reorganized by virtue of
Maxim's efforts on the basis of ideas I told him I felt he must accept and try to carry through, and those ideas he did accept.

NELSON: According to the midget issue of QST, which is the one of eight pages — two sheets — this shows four of the eight pages, right here, the issue published between the time of suspension and just prior to resumption of publication, bonds were issued and that started the publication back on the going track again, just as was discussed by Mr. Godley and Mr. Maxim.

GODLEY: I think they raised $7,500, which of course isn't much money now, but it was a heck of a lot of money then.

NELSON: Paul, I wish we had more time. We could talk another hour, but our time is about to catch up with us. Is there any one thing that sticks out in your mind that you would like to give us a parting thought; your thrill of hearing the first American signal or one instance that comes to mind readily?

GODLEY: Well, this is a philosophical note, in a way. One of the things that supported me during my difficult teens and early twenties was in the words of the very famous and great poet, Goethe: "Whatever you do or dream you can do, begin it; boldness has genius, power and magic in it."

NELSON: Paul Godley, we are delighted to have had you with us, and to a man, we've thought of you with admiration and we thank you so much. It has been my pleasure.

GODLEY: Thank you, all of you.
