THE A.W.A. REVIEW

EDITOR
Robert M. Morris, W2LV
Sparta, N.J.

MANAGING EDITOR
William B. Fizette, K3ZJW
Henryville, Pa.

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THE COVER
A photo-montage of the new Radio City Studios of NBC to which the NBC network operation moved from 711 Fifth Ave. in late 1933. Included is a view of Studio 8H, the largest broadcast studio at that time, and a view of the large master-control switching center. Shown also is the main entrance, the studio foyer and corridors as well as several of the smaller studios. In the lower corner is a view of the unique control and monitoring panel for the extensive studio air-conditioning system. These studios were all adapted for television, beginning with Studio 3H in 1936.
(Photo courtesy of National Broadcasting Company, Inc.)

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FOREWORD

Volume 3 of the *A.W.A. REVIEW* presents seven papers which should be of interest and value to both collectors and historians. An unusually fine complement of photos and illustrations includes the cover photo, for which special arrangements were made. An added feature is the inclusion of brief sketches of the authors.

The first paper is the third and final chapter of the Atwater Kent story, by Ralph Williams. This takes us through the middle and later years of the company and concludes with the closing of operations and Atwater Kent’s retirement.

The next two concern early broadcasting, and provide factual information which might otherwise be difficult to obtain. Following these, Alan Douglas, A.W.A.’s most active historian, presents an unusual bit of research, even for Alan. It describes the origin of a little-known patent situation which became of great interest and significance in the development of broadcast receivers in the late twenties.

The paper by Lauren Peckham is a classic, and includes photographs of most of the famous Mignon receivers. It probably contains all of the information on Mignon and his radio equipment that will ever be available.

The joint presentation by Moreau and Willer on telegraph and wireless keys supplements the one by Moreau in Volume 2, and includes material presented by Murray Willer at the 1987 A.W.A. Conference. Many excellent pictures are included to aid collectors in identifying various keys.

The final paper, by Glen Fuller, represents considerable research on his part into aspects of the great Alexander A Alternators little known by anyone now living. The mechanical design as well as the unusual and complex control systems of these remarkable machines are described.

Finally, this issue of the *REVIEW* is favored with a guest editorial by Donald Christiansen, an A.W.A. member who is also the editor and publisher of what is perhaps the world’s most prestigious and widely-read scientific and technical publication, the *IEEE SPECTRUM* of the Institute of Electrical and Electronics Engineers. Here are some very worthwhile words of wisdom, based on experience.

Sparta, N.J.  
August, 1988

Robert M. Morris
GUEST EDITORIAL

When editor Morris invited me to pen a commentary to accompany this third volume of the A.W.A. Review, I told him I was honored to be asked and would be delighted to do so. Clearly the journal has gotten off to a commendable start. Aside from the obvious dedication of the editor and his authors, I reflected on what the journal has going for it. I thought of these things.

History is at best difficult to record. But most A.W.A. members share a valuable characteristic in that they, like their predecessors, see the radio business/profession as a calling — not merely a job. Because of their personal interest and involvement, they have retained artifacts and documents that might otherwise have gone to the scrap heap or to the shredder. (Even so, think of all the lost corporate records that might have yielded a cornucopia of valuable historical information!)

This brings me to my third point. It is a reminder to all of us that a good bit of history is written behind the scenes. The reminiscences we exchange at radio club meetings, ham fests, and swap meets are important. The perceptions gained of inventors, entrepreneurs, and other personages in the radio field are important, too. The professional historians would, properly, warn us to clearly delineate opinion from facts and figures, but opinions and perceptions, I would submit, complement factual history and help the student of history to understand the dynamics of innovation as well as the sociology of radio history.

Recent presentations at A.W.A. have elaborated upon the personalities and even the idiosyncrasies of the pioneers in our field. Properly recorded, such information can only enhance our understanding and enjoyment of radio history.

Donald Christiansen
Editor and Publisher,
IEEE SPECTRUM
Member, Antique Wireless Association
ATWATER KENT RADIO DEVELOPMENT — PART III
THE A.C. POWERED RECEIVERS

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

INTRODUCTION

Continued growth of the AK Manufacturing Company in 1926 demanded major changes in the appearance and the performance of the radios that had, up to then, brought great success to the company. (see: ATWATER KENT EARLY RADIO DEVELOPMENT — THE MAHOGANY AND METAL BOXES, THE AWA REVIEW, Volume 2). In only five years, radio receivers had progressed from single-tube detectors through regenerators to one-dial TRFs. Their sound had changed from the tinny tone of metal horns to the soft voices of magnetic cones. Power for the sets was changing from batteries to line-powered A and B eliminators. Radio was no longer a novelty; it had become an important part of household life.

The market was ready for better radio sets, and new technology made them possible. Progressive manufacturers incorporated the new tubes that operated with A.C. filament power, the higher-powered audio output triodes, the full-wave rectifiers and the electrodynamic loudspeaker into modified designs that ultimately made the radio set a convenient home appliance. The story of AK products during that time gives a good picture of the problems that all had to solve, and how AK went about solving them. Part 3 of this series picks up the story at the time when the house-powered, alternating-current radio set became a reality.

FROM MAHOGANY TO STEEL — THE MODEL 36

For AK, the electric-radio concept came together in the Model 36, Fig. 42. The underlying design of the signal-handling part of the set had been completed with Model 33, the seven-tube battery receiver that was the top of the line in late 1926. With the slightly modified Model 33, and a power supply derived from the Model R Power Unit, the electric series was born.

Model 36 used a new tube, type 226, for its radio and audio amplifiers because the 201A tube was not satisfactory with A.C. heating its filament. With the exception of its 1½ volt filament, the 226 had the same operating characteristics as the 201A, and consequently required no changes in circuit parameters. For detector operation, however, the 226 was not satisfactory. To overcome the limitations of a directly-heated filament, another triode having nearly the same operating characteristics but using a coated-cathode cylinder to emit electrons had been developed. This one, type 227, was free of hum and
made an excellent grid-leak detector. Because the 227 added a cathode element, it was given a five-pin base. Only minor changes were made to the mahogany box to accommodate the A.C. filament tubes and to the cable to bring filament power for them from the power supply; e.g., AK recast the detector shelf to accommodate the extra pin of the detector tube.

At about this same time, the middle twenties, another very pertinent radio receiver problem, audio-output power, was being solved. Operating a battery radio that could produce high power was far too expensive for the ordinary home. With the advent of the electric set, however, the demand for audio power could be economically met. A new output tube, the UX171 (later 171A) was developed by Westinghouse and made available by RCA for much enhanced receiver performance. It could produce several times as much power output as the 201A but it used more current, operated at a higher plate voltage and had to be biased.

The Model R power unit that AK had marketed as a B-eliminator had to be redesigned for Model 36. The transformer design and the filters were adequate but the rectifier (Part No. 607, an argon gas tube) was severely limited for increased current applications, especially when operated at high enough voltage to provide for both the plate and bias requirements of the 171A. The needed improvement resulted from the development of high-vacuum, full-wave rectifier tubes by GE and Westinghouse. These included the type 213, the first commercially available full-wave rectifier (also limited for this application), and type 280, an upgraded 213, which met the requirements admirably. Model 36 and all but one of the subsequent AK receivers included the 280 rectifier or its octal version (5Z4).

* Note: The first 41 pictures of the Atwater Kent radio sets are in THE AWA REVIEW, Vol. I and Vol. II. The story continues here, with the illustrations starting at Fig. 42.
Model 36 looked and performed very well, as did the battery version, Model 33. Both sets were marketed in 1927 but about twice as many Model 33s were produced (70,000) as Model 36s. It may be that Model 36 was really a transition set whose function was to permit AK to get into the market before the version he wanted to produce, Model 37, was ready. In looking back, the Model 36 is one of the more interesting sets in the AK line. Its style marked the end of the battery era and at the same time its use of house-power began the new era that made the radio a modern necessity.

**THE MODEL 37 — STEEL STYLED FOR PROGRESS**

In reviewing the few records that are still to be found about AK it becomes clear that 1927 was a busy year for his engineering force. Not only were the Models 33 and 36 brought to market but the next set in the series, Model 37, was also introduced. This receiver, Fig. 43, was the first one to incorporate a power supply, together with the radio and audio circuits, in a single enclosure. The appearance that the modern Model 37 made in a living room of the late twenties was quite an improvement over the passé look of the earlier mahogany boxes. The metal case left an impression of the benefits of technology, where the older wooden boxes were only variations of common household containers. AK was very much in tune with the attitude of the times in using the steel enclosures.

Because the steel industry, together with the automobile industry, had developed ductile steel and suitable machine tools for shaping large body panels, an ordinary individual would have been familiar with the changes in car fashions and welcomed the results. The new automobile styles made

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Fig. 43. Model 37

*Photo: R. Williams*
everyone aware that steel shaping was a wonderful improvement. Closer to the home, the wonders of steel were revealed in new major appliances like the refrigerators and ranges that became the energy-servants of the housewife. With this favorable attitude toward shaped steel, the novel metal radio cabinet of Model 37 conveyed the impression that the world approved the choice.

AK must have had a very clear picture of the acceptance of the metal radio box. The sales of Model 35 were abundant evidence that style was selling radios since that set was really a repackaged Model 30. Although AK advertised one-dial tuning for Model 35, that advance alone was not enough to account for Model 35 selling twice as well as Model 30. The steel box, the reliable circuitry, and the Model Y power supply from Model 36 must have looked like pure gold to the marketing people at the factory. All that was needed was to expand the plant so as to be able to fabricate Model 37 cabinets in quantity, and that was one of Mr. Kent’s specialties. The AK story shows that the factory was busy, since the difference between making set number 1,000,000 (a Model 35) and making set number 2,000,000 (a Model 40), a year and a half later, was the one in between, Model 37.

The Model 37 steel cabinet was designed to be relatively easy to fabricate. Three pieces made up the box with a fourth piece shaped to make the cover. The bottom was a simple flat-punching to which the front and back pieces were spot welded. The front was complex but not as difficult to draw as the Model 35 case. It was formed as a channel about thirty inches long. Then it was restamped to form the corners. The rear piece was pressed similarly. During the drawing sequences, the various holes were punched for the dial shaft, the antenna attenuator, the power switch and the rear accesses. Properly shaping and sizing the cover took the highly skilled metal-drawing work that characterized the AK factory. The fit between the cover and the main box had to be very close. A few thousandths too small and the cover didn’t go on. A few thousandths too large and the cover was sloppy. While good practice indicates that all the covers produced for a particular model should have been the same size (and the specified dimensions), and that all the boxes should also have been correct, they weren’t. The covers made for one run of sets do not necessarily fit others. Present-day collectors know how difficult prying off a good looking cover can get.

The characteristic decoration of Model 37 was the ship nameplate, a coined medallion that was first used on Model 35. It was fastened in the center of a rectangular panel outlined on the cover by stamping during the fabrication process. The panel was painted gold wrinkle to contrast with the brown wrinkle finish on the rest of the cabinet. On Model 37 the panel was flat but on later sets the panel was slightly convex. Some of the flat-panel covers were used on the early Model 40 radios, perhaps to zero the stock before the improved (stiffer) covers were produced. The other recognition feature of Model 37 was the dial with its vernier. The dial was brown, reading from 0-100 clockwise, and first used on the late Model 10. The vernier was gold-plated and went back even further to the coupled-circuit tuner.

In the same way that AK made only minor changes to go from Model 33 to the signal circuits of Model 36, his engineers started with the Model 35 chassis,
altered the filament circuitry, changed to an input attenuator and bolted the entire assembly in the new metal radio that became Model 37. Again, the tubes used in Model 37 were 226, 227, and 171A. In order to integrate the Model 36 power supply (Model Y) in the single cabinet of Model 37, the power supply had to be mechanically redesigned. Electrically, no changes were necessary but the arrangement, especially the enclosure, was not usable. A smaller, rectangular sub-case was designed to enclose the transformer, the condensers and the chokes. The connection panel was mounted at the top. To interconnect the signal unit with the power supply, the cable was redesigned to be shorter and to follow a smooth path between units.

Model 37 has maintained a reputation as a good performer. Over the years since it first appeared, the main failure has been puncture of the paper dielectric in the filter condensers. During the active years for the metal-box sets, when customers needed dealer service, repair was made by replacing the entire power unit. Present-day collectors, troubleshooting a failed power supply, occasionally find that the high-voltage winding of the power transformer has also been damaged. This is usually a secondary fault caused by the shorted condenser and an 80 rectifier tube that could be heavily overloaded. Sometimes in a restoration, the 80 is found to be defunct but that has saved the transformer. Nevertheless, replacing the condensers is an adventure in working with potting tar.

Two versions of Model 37 were produced. The difference between them was in the tuning condensers. The earlier sets used 17-plate tuning condensers, the later ones used 13 plates. The radio-frequency coils were changed to correspond with the change in tuning capacitance while maintaining coverage of the broadcast band. The early version was identified by the tube chart pasted to the front of the power supply (near the top). On the later version, the chart was located on the bottom of the cabinet between the signal chassis and the power supply.

PARALLEL PRODUCT LINES AND THE MODEL 38

AK carried parallel lines of receivers through all the model years of his production. Parallel product lines were the result of customer preferences. The first directly-related example of parallels was Model 10 with Model 12 (Radiodynes). In the mahogany boxes, Model 30 paralleled Model 32 (or 33). There even appears to have been a six-tube version of Model 20, identified as Model 22. The parallels continued into the metal box production; Model 37 was accompanied by Model 38. Some families were pleased with the standard, highly effective, seven-tube radio that was AK’s main offering. Others wanted the more expensive, slightly more sensitive and probably more impressive eight-tube, top-of-the-line receiver.

Model 38 used the radio and audio circuits from Model 33, added the power supply developed for Model 37, and utilized a cabinet that was about four inches wider than Model 37 to accommodate the extra radio amplifier. The changes in filament and output circuitry that were necessary to use the new
alternating-current tubes were the same as those made for Model 37. The other similarities were the brown dial, the gold vernier and the ship medallion.

Models 37 and 38 were excellent radios in their time. They were sensitive, selective, and provided good volume on all but the weakest signals. They could be overloaded on very strong signals but with a good ground the volume control was effective. Two irritating features (common to many tuned-radio-frequency amplifier receivers of that time) were difficult tuning at the high-frequency end of the dial, and excessive signal variation as the set was tuned over the band. Because of the many pleasures that Models 37 and 38 brought into the home, those flaws were not noticed. Although exact figures are unavailable, the total production of Models 37 and 38 appears to have been upwards of half a million.

THE STEEL CABINET RADIOS, MODELS 40, 42 & 44

Based upon the immediate success that AK enjoyed with Model 37, it must have been easy to decide what to do for 1928. Manufacturing had only to keep the production lines operating at full speed. Engineering was to make only minor changes to the design, minimize costly impacts on production, and change the appearance of the set enough to assure clear and separate identification in the marketplace.

For 1928, the seven-tube (standard) radio became Model 40. The eight-tube (top-of-the-line) receiver that replaced Model 38 was Model 44, Fig. 44. From

Fig. 44.
Model 44 Desk

Photo: R. Williams
the viewpoint of a technical historian, the changes were uninteresting. From the entrepreneurial viewpoint they were very significant, because they were so minor. They were a study in how little, rather than how much, had to be done to make a model change in a seller's market.

The changes in appearance were a new cover that was slightly convex in cross-section, and a new decorative medallion. The new decoration was hexagonal in outline and art-deco in its look. The traditional ship was replaced by a figure that spoke of the new progressive world. If a customer looked inside he would have seen no changes to the signal circuitry, although the antenna potentiometer was a little different, but he could see a new power supply. The enclosure had been changed from a folded box to a drawn enclosure and cover, not so much to provide customer appeal, as to reduce production costs. Altogether, the changes were characteristic of a continuing product, not a new one.

A review of the entire product line introduced for the 1928 selling season emphatically shows that AK was not satisfied to merely replace the successful Models 37 and 38. Clearly he intended to expand his market by extending his total line of sets while limiting the design costs. One segment of the market that needed a better set was made up of homes on the peripheries of the alternating-current, power-distribution networks. The other segment was the large market served by direct-current distribution systems. The design of Model 40 was modified slightly to solve these two house-power problems.

THE LINE REGULATOR MODELS 42 AND 44

In the twenties, the line-voltage regulation on the fringes of some alternating-current distribution systems was sometimes very poor. If the nominal 110-volt line dropped to 95 volts, radios were subject to failure because the filaments cooled too much for satisfactory emission. To cope with the excessive voltage changes, AK brought out Model 42, which incorporated a series regulator in the primary of the power transformer. The nominal voltage required by the transformer was about 70 volts. The regulating resistance took up the difference, whether it was 40 volts, based on the normal line voltage, or a lower value, e.g., 20 based on a line voltage of 90 volts. The same changes were made in the eight-tube set that was derived from Model 38 to make Model 44.

Not all alternating-current generating systems operated at 60 Hz. The stations at Niagara Falls produced prodigious amounts of power but it was at 25 Hz. AK's designs were adequate for 25-Hz service except for the power transformer. AK altered Models 40, 42, and 44 to meet the needs of the 25-Hz market by substituting transformers having higher primary inductance and by adding filtering. These sets were identified with the suffix letter F.

THE DIRECT CURRENT RADIO — MODEL 41

Edison and the proponents of alternating-current distribution systems engaged themselves in protracted arguments about which was the better way to generate and distribute electricity. Edison championed direct-current distribution
with the result that the residents of many cities could not benefit directly from the greatly improved A.C. radios that were the thrust of the late twenties. AK saw the D.C. market as very profitable and easy to penetrate because Model 37 had already solved two-thirds of the problem: the signal chassis and the cabinet. It was again a simple matter to modify the filament circuits and add a direct-current filter for the main power. Type 112A tubes were substitutes for the 226 amplifiers and the 227 detector.

The normal plate voltage used for operation of the triode amplifiers in Model 40 and similar alternating-current sets was in the range of 140 to 155 volts. The direct-current set, Model 41, did not have the benefit of voltage step-up in a power transformer, so its maximum plate voltage was little more than 80 volts. Because direct-current mains were noisy, additional filtering was necessary for the low-level amplifiers and, therefore, their plate voltages were only about 65 volts. Reduced plate voltage resulted in reduced stage gain. To make up for the loss in overall gain, the output stage was made push-pull. This nearly doubled the overall receiver gain, and almost made up for the gain reduction caused by the low plate voltage. The push-pull output tubes, 171As, were transformer coupled from the first audio amplifier and shunt-fed in their plate circuits. The loud speaker was connected directly from plate to plate.

Since extensive production changes were undesirable, the extra output tube was fastened to a tube shelf attached to the power supply enclosure. This was similar to the way the rectifier tube socket in the alternating-current sets was fastened, but it was attached to the other end of the power supply enclosure. Adherence to AK's precept of limited redesign was exemplified by the fact that the amplifier socket was the same phenolic part as the rectifier socket in Model 40. The bracket and the screws were also identical in the two sets. Model 41 was the last of the three-tuning-condenser cabinet sets to use the Model E magnetic loudspeaker.

Model 41 performed well, partly because it was generally used by city listeners. The capability of the set to select stations was the same as the other receivers in the three-tuner series, but the sensitivity was a little lower for those who wanted full loudspeaker volume. Few present-day collectors have gotten their Model 41 receivers working, usually because of the daunting task of providing an adequate direct-current source. They do perform well, however, when they are tracked and adjusted.

**THE ELECTRODYNAMIC SPEAKER — MODEL F**

Improvements in loud speakers came slowly during the twenties. Not until 1928 was AK able to make the arrangements that were necessary to begin production of his first dynamic speaker, the Model F. He had to arrange patent agreements, perform experiments, design the elements of the speaker and its protective enclosure, and set up production facilities in order to manufacture enough dynamic speakers to satisfy his market. At the same time, his engineers had to modify the output circuitry in the receivers chosen for use with the new dynamic loud speaker. The first receiver offered with a dynamic speaker was Model 43. Models 46 and 47 were supplied with Model F2 dynamic speakers.
AK electrodynamic loud speakers, such as Model F and Model F2, were self-contained, self-standing metal drums inside which the speaker frame and field structure were fastened. The difference in those two speakers was in the size of the drum-shaped enclosure. Model F was the smaller, about 10 inches in diameter, with a flanged front about two inches larger. Model F2 was a regular, slightly-flat horizontal cylinder a little over 13 inches in diameter. Acoustically, both speakers were the same.

The Model F electrodynamic loudspeaker was magnetized by a field coil wound with many thousands of turns of fine enameled copper wire, and connected to act as a filter choke in the power supply. Its voice coil measured a little over an inch in diameter, and was connected to a cone about 10 inches in diameter. The speaker worked reasonably well down to about 100 Hz. This was so much better than the type E magnetic speakers that it ushered in a new world of expectation of how a radio should sound. Part of the attraction was the increased power that the speaker could handle, and the rest was the extended low-frequency response. Present-day assessment of the sound usually leads to the comment "boomy," which suggests that the response peaked near 150 Hz.

**MODELS 43, 46 & 47**

The increased power that the dynamic speakers could handle had to be supplied by the radio, so revision of the output stage was required. This was done by changing the single-ended stage used in the Model 40 to a push-pull amplifier for Model 43. For the first time in the line of AK receivers an output transformer was used. It was used to change the small voice-coil impedance to the several-thousand-ohm loading required by the two output tubes. Room was made by removing the output choke used on the earlier sets. Because the extra output tube could not be fitted on the tube shelf with the other one, a second shelf was added to the right end of the power-supply enclosure opposite the rectifier. Aside from minor changes to the main power cable, increased supply capability of the main power transformer and substitution of the speaker field coil for one of the filter chokes, no other changes had to be made. No changes were made to the signal chassis, again exemplifying AK's precept of limiting changes while significantly increasing the radio set's appeal to potential customers.

The picture that emerges of AK's factory operations shows very effective control of the production process. Therefore, the engineers who converted Model 37 to Model 40 must have worked on that project early in the spring of 1928. Next came the work on the regulator for Models 42 and 44. After that they designed the modifications to the receiver that accommodated the dynamic speaker. Probably that work was completed in the fall of 1928. The radios that resulted were not only Model 43 but Models 46 and 47.

Model 43 was, in effect, Model 42 with push-pull type 112A tubes in its output. Model 46 was similar in having a push-pull output stage but it used 171A tubes, and omitted the primary-power regulator. It was an upgraded Model 40. Model 47 was the eight-tube set that was directly derived from Model 45,
Fig. 45. Circuit for Model 43, similar to Models 46, 47, and 53. The output transformer is sealed in the power unit.

but incorporated the push-pull output stage of Model 46. Fig. 45 shows the circuit for these higher-power sets. They were put on the market as soon as they could be produced, instead of waiting for the annual model change. They had so much to offer in the quality of their sound that AK must have hurried them to assure his continued popularity with the radio public.

MODELS 45, 48 & 49

In telling the story of the development of the first series of AK alternating-current receivers, the author has blended information from many diverse sources; the order of the model numbers; the sequence of the part numbers of the radios (not always in the same order as the models); lists of the part numbers in each set; the data gleaned from advertisements in the public magazines, and releases in contemporary trade journals. Using that information in the context of life in the late twenties, and adding the experience obtained by working with the radios themselves, a story of the technical and business development of the AK Manufacturing Company has emerged. But things don’t always go smoothly, even in stories, and some of the sets do not fit into their expected places. Model 5 is an example. By the time it was released, Model 5 had become an anachronism. Models 48 and 49 have the same puzzling character. Model 45 needs an explanation because it was so similar to Model 44. Model 50 was strange compared to the rest of the family. It also deserves special consideration.

Models 48 and 49 were almost identical to Models 30 and 33, but they were produced about two years later (1929). Some of the sets, more commonly Model 49, were equipped with gold-painted panels, perhaps reflecting upgraded modern decoration in keeping with the metal-cabinet sets. But then, some
were identical to the 30 series with brown panels. More puzzling was the fact that Model 48 appeared in both the form of the first version of Model 30 (bayonet sockets) and the second version (push-pins). However, both versions of Model 48 had the deeper cabinet first used on the third version of Model 30. Perhaps the market for battery radios continued at a high enough level to justify another production run for each set, but why wasn't the design of the fourth version, Model 30-A, used as the basis for Model 48? Could it be that there were parts left over in those stock bins?

Model 45 was late enough in the sequence of the 40 series that it missed the 1928 holiday-selling season. The puzzle, however, is in its part number, No. 9880, which was assigned before those of Models 43 and 44. In AK's market planning, Model 45 may have been conceived but delayed. The part number tended to indicate the point where the idea was committed but the model number indicated when manufacturing functions, i.e., purchasing and factory planning, were turned on. Model 44 was the upscale (eight-tube) radio that was paralleled with Models 40 and 42. Model 44 was equipped with the primary-power regulator circuit. Model 45 was the direct replacement for Model 38 (upscale but no regulator) for those customers who wanted the more expensive receiver. But since Model 44 served the high end of the market, bringing out Model 45 along with Model 44 was not really good business. Model 45, when it was released, was one of the first radios in the AK line to be finished in the glossy near-black finish that supplemented the crinkle brown, standard in the 1928 series of sets. Perhaps Model 45 became part of the next year's line, replacing Model 44 with the new look of modern dress.

THE MODEL 50

In examining the sweep of AK radio receivers, the similarity of signal circuitry that any single set bears to other sets made at about the same time is striking. The underlying design was slightly modified many times, but it was not displaced from the time of the three-dialer (Model 10, 1923) to the last tuned-radio-frequency amplifier sets (Model 70 series, 1932) — except for Model 50.

Model 50, Fig. 46, provided three passive, coupled, tuning resonators to select the signal of interest before it was passed to detector level in a multistage, broad-band amplifier unit. The rest of the set was similar to other battery sets, e.g., Model 30. Analytical modeling of radio receivers (developed long after AK was out of the manufacturing business) shows that a better receiver can be built if it can select the desired incoming frequency from the spectrum of other signals and noise before any amplification is permitted. The part number of the set, No. 8500, indicates that it was first considered at the time of Model 33, perhaps as part of the effort to reduce the detuning effect of tube-replacement reactance in the ganged radio-frequency amplifiers of the 30 series.

To the technician interested in the history of receiver development, Model 50 is fascinating. To the historian interested in the growth of the radio business, radios like Model 50 are little more than ripples in the stream. From
the small number of Model 50 receivers that have survived, the author concludes that AK saw no business value in including the set in his line of alternating-current receivers. The puzzle is: based on number sequences, the part number points to 1927 for design work, but the model number points to 1929. Did the concept drag on for nearly two years before the set was put on the market? Since it was late, and didn’t sell, why did it appear at all?

**CONSOLES AND THE “LITTLE STOVES”**

In the mid-twenties the majority of the potential customers for radios preferred table models. The idea that radios were also furniture was still in the future. Some customers, however, wanted their radios to be self contained, so a secondary radio-receiver assembly business whose purpose was to meet those needs grew along with the general expansion of radio manufacturing. Usually the form of the radio enclosure was a self-standing console that carried the radio, the loud speaker and the power source. AK sold his radios to furniture companies, e.g., Pooley or Red Lion, who then assembled the complete unit and handled the marketing.

With the advent of the electric set, assembly into consoles became much more practical. As consoles became more popular, styles and suppliers proliferated.
AK resisted the trend, possibly because he preferred the cabinet set, but more likely because he had become a high-quality producer of metal-enclosed radios, and console production was a specialty business based on wooden furniture. To accommodate the console suppliers, AK provided complete cabinet sets, case and all, which were hidden behind a fancy panel. Cutouts in the panel provided access to the controls. Model E loud speakers were redesigned by eliminating their cylindrical cases and providing a flange around the cone. Modification of the dynamic speaker was not necessary. AK simply supplied the loudspeaker without its enclosure. The plain unit was identified as Model F-2C. (C indicated use in a cabinet or console).

At about the same time as the 40 series was put on the market in the form of table-model receivers (with some being incorporated into consoles), AK redesigned their steel cabinets to make them into free-standing floor models. Short legs were attached to the bottom of the resulting rectangular box, thereby placing the dials at a convenient height, about 27 inches above the floor. The extension (the space below the radio) was used to house the loudspeaker, making the first fully integrated series of radios in the AK line. The pressed-steel consoles corresponded exactly to cabinet sets in the 40 series. They were assigned model numbers in the 50 series. Model 51 was a direct-current radio that was identical to Model 41. Model 52 was the same as Model 42.

Model 53, Fig. 47, is a little more interesting to collectors. The electrical circuitry was the same as Model 43, including the dynamic speaker. The console

![Model 53 Console](Photo: R. Williams)
for Model 53 was four inches shorter than the other two, perhaps to make a chairside radio. (The set would have been just right to use with a Morris chair.) The Model 53 was offered in several different paint combinations; brown crinkle with gold, gloss black with green, and medium green with gold pinstriping. To the contemporary homemaker, the radio was an interesting and apropos addition to the living room. To the present-day observer, the design is so strange that these consoles are referred to as “little stoves.” There were two others, Model 56 and 57. Both used the circuitry from Model 40 (no regulator). Model 56 was the taller and looked like Model 52; Model 57 used a lower cabinet that was similar to Model 53.

THE SCREEN-GRID TUBE AND MODEL 55

During the first World War (1916), German tube researchers, particularly Schottky, studied the triode and the effects of extra electrodes on its performance. Their work led to accurate characterizations and some use by the German military, but it was not used by American tube manufacturers to develop a commercial tetrode until the middle twenties. When it appeared in 1926, the D.C. filament version was designated UX222. For electric radios, the further development of the tetrode to incorporate the unipotential cathode was necessary. That work took place in 1928 and the result, the UY224, was announced in April, 1929.

One result of the action of the second grid was the isolation of the control grid from the plate. It was, in effect, a screen, and this function gave the new tube its valuable advertising name, the screen grid. Another characteristic change was to reduce the effect that the plate voltage had on the electron stream, thereby increasing the place resistance and the amplification factor. Because of these different tube parameters, the screen-grid tube could be used as a stable high-gain radio amplifier without neutralization. As soon as RCA made the 224 available in the summer of 1929, AK brought a radio to market using that tube. It was designated Model 55.

The opportunity to develop a new line of radio receivers which was brought about by the introduction of the screen-grid tube caused a major stir in AK's engineering activities during early 1929. A whole list of requirements had been accumulated; here was the opportunity to meet them. For the first time in nearly five years, the radio amplifiers in AK’s receivers could be redesigned (of course the tuning condensers, the tracking bands and the general layout were acceptable), but the coils and their circuits, their orientation and their mountings, had to be new. Earlier receivers using triodes included very little bypassing, but with screen-grid tubes screen and cathode tie-downs became important. Consequently, the older style of tube sockets and attachments were inadequate for the resistors and condensers needed in the new sets. Mechanical integration of the power supply in the total radio enclosure was a requirement that had been met only marginally in the 40-series electric sets. Console radios had become prevalent enough by the middle of 1929 to make it necessary to include their requirements in any new design.

Taken altogether, these new demands, the results of earlier successes, called for a totally new mechanical design. The days of the steel cabinet were
numbered, but the superb metal-shaping facilities that AK had developed were still in place. Integrating all the demands in a new, producible, easily-assembled mechanical structure called for another first in the AK line of radio sets. It was the concept of a planar chassis with shallow, stiffened edges, whose strength was sufficient to structurally support all the components in the receiver during assembly and shipping. Its shape was selected to simplify fabrication, and its size (10” x 21”) was chosen to fit into the steel cabinet used for Model 45. The radio that was built upon this new chassis was Model 55, Fig. 48. When the radio was to be supplied in the metal cabinet, the controls passed through penetrations in the front of the enclosure in a manner similar to the 30 series. AK, realizing the trend toward wooden floor-consoles, arranged the design of the chassis to accommodate a metal dress-panel through which the control shafts passed, and on which the dial escutcheon was mounted. The panel was finished in simulated wood-grain. It was used to close a big opening (9” wide) in the face of a console. A chassis that included the dress-panel was marked with the suffix letter C.

The power supply and the audio circuits for Model 55 were adapted from Model 46 with minor changes, e.g., the output tubes were changed to type 245 and the filament circuits for the whole set were 2½ volts. The big change was the use of 224 tetrodes as radio amplifiers. This increased the stage gains (and improved selectivity) enough to make a power detector practical. The result was a very sensitive electric radio with higher output power and lower harmonic distortion than anything AK had produced before. Model 55 became
the main sales attraction for the 1929/30 holiday season. It was with this radio that AK started his campaign to emphasize “Tone”.

By 1930, radio had become a vital part of American life. The broadcasting networks had matured to the point where their programs were shaping the way people arranged their lives, i.e., news at the supper hour, programs in the evening. AK utilized the growth of broadcasting to build his product image. He sponsored a serious music hour that was broadcast on Sunday nights over a coast-to-coast network of 31 stations. To reach another segment of his customer audience, he offered a mid-week program of popular music over a smaller network of eastern and mid-western stations.

**MODELS 60, 61, 66 & 67**

In the same way that Model 44 paralleled Model 42, Model 60 was the upscale version of Model 55. The chassis and the arrangement of the tuning condensers used on Model 60 were similar to Model 55, except for the addition of another radio amplifier. AK advertised Model 60 as being more sensitive (than 55) but the text was careful to indicate the benefit was for rural areas. In general, the contribution of the extra stage was cancelled by the volume control. In 1930 AK made a big change in the way he built the radio-amplifier stages of his radios. He went away from the tracking bands (his patent) to the use of a single-shaft, multiple-section variable condenser (J. V. L. Hogan’s patent). This change resulted in a mechanical redesign of Model 60 which was designated as the “3rd type.”

In 1930 the number of listeners who needed direct-current radio receivers was still large enough for AK to produce brand-new sets for that market. The customers divided into groups; those who had direct-current housepower, and those who needed a battery-powered radio. For both of these users, AK modified the Model 60 to use type 222 tetrodes, type 112A triodes and type 171A output tubes. The radio to be used on the direct-current mains was Model 61. The battery version was Model 67. The differences between the sets were in the power supply and the loudspeaker field coils. Model 61 filtered the mains and used a Model F6 speaker with a high-resistance field. Model 67 used A and B batteries with speaker Model F7 (field operated from the 6-volt A battery).

The last set in the 60 series was the high-powered member of the group, Model 66. It was very similar to a plain Model 60 except for the output; Model 66 used push-pull type 50 tubes. The demand on the rectifier tubes exceeded the capability of the type 80, so a pair of type 81 half-wave rectifiers was used. Model 66 was not offered in the metal cabinet that had become AK’s symbol. Because it was sold through the console manufacturers and offered so much power, the author suggests that it was built for the custom market.

**THE 70 SERIES**

The concept of introducing a new series of AK receivers annually was well established by the year 1930. To be ready for that year’s holiday-sales season,
a new series of receivers had to be made ready. Acceding to AK’s precept of minimum technical change and, at the same time, responding to customer preferences, the new line (the 70 series) was derived from the Model 60, especially the third version with the multi-section tuning condenser. To provide a wide range of choices to his customers, AK provided six different chassis types and four enclosures, all consoles. One console was a radio-phonograph, Model 75, Fig. 49. Clearly, AK had gotten the message about the marketability of console-model radios.

At this time, a customer who wanted to buy a table radio bearing the AK name had to accept an earlier model. Looking back from the view point of another half century, not offering a cabinet set in the 70 series might seem to have been arbitrary on the part of AK and his staff, since we know that compact receivers were about to become popular. More likely, the 1930/31 season was the crest of a wave that gave great status to having a radio, and greater status to having an AK. The very bad situation that started with the stock market crash of 1929 had not spread to the class of buyers that were AK’s main focus. The country tried to keep the romance of the twenties alive as long as it could; and only doom-criers took comfort in the financial and commercial downturn that was about to overtake everyone. From AK’s standpoint, opening a new low-end market might have been nearly impossible, since he announced set number 3,000,000 in October 1930. At that time he was producing at the rate of 50,000 sets per month. It may be suggested that there was no point in AK’s doing anything else since he was riding the top of the wave. This evaluation fails to account for AK’s demonstrated business vision and market perception.
Electrically the radios type L, (10-tube TRF), type F (25 Hz), type D (D.C. mains), and type Q (battery) were unremarkable if compared to the preceding Models 60. They had one interesting mechanical feature, however. The chassis was punched out in two 12”x10” pieces, each a little more than one-half the size of the Model 60 chassis. The joint between halves ran from front to back and provided an immediate identification detail. The half-chassis would have required smaller presses than those used to form the Model 60 chassis. Some of the presses used to make earlier cabinets could have been used to make 70-series chassis-halves while the Model 60 presses were still busy.

Another chassis, type H, Fig. 50, was provided as an option to Model 70 series customers. This one was very different; it was the first superheterodyne produced by AK. Fig. 51 shows the early version of its circuit. For nearly a decade the patent rights to the superheterodyne had been held (tightly) by the Big Three, more specifically the Radio Corporation. As one of the many results of the separation of RCA from GE and Westinghouse, the licensing of the superheterodyne patent was extended to all interested manufacturers. Whether the circuits based on the superheterodyne were better than the TRF circuits was an argument among technicians. The clear advantage was in the manufacturing costs for radios of equal performance that were built to be used in the home.

AK’s first superheterodyne did not take advantage of the cost reductions, however, since it was really an adaptation of the TRF in mechanical and circuit details. As later designs demonstrated, selectivity in a superheterodyne was obtained from the transformers in the intermediate-amplifier stages. The first version of Model H used three sections of the variable condenser in a passive tunable filter (more than a little reminiscent of Model 50) to do the same job that the intermediate-frequency amplifiers could do. That version, H-1, used separate, uncoupled chokes and coils in the intermediate-frequency amplifiers. The second version changed the chokes to double-tuned transformers whose coupling was controlled by their mechanical spacing, in what became the standard design.
Fig. 51. Model H-1 Chassis Diagram
All the receivers in the 70 series performed well. They were sensitive, powerful and provided good tone. In part, the tone was the result of the cabinet size and its resonance. The quality of the sound led the advertising people to dub the 70 series as “The Radios With The Golden Voice.” This feature was pushed very emphatically in print and radio advertising, especially by programs given in the sixth year of the AK Hour on the national radio network of 34 stations.

THE 80 SERIES

The impact of licensing the superheterodyne patents from RCA was total revision of the AK product line. Although the new circuit was first introduced as a single set, the type H chassis in the 70 series, it presaged a major change in the radios in AK's 1931/32 product line, the 80 series. All of the radios brought out for the 1931/32 model year were superheterodynes except the auto radio, Model 81. Specifically, eight models made up the 80 series of superheterodynes, but many of these had AK-standard suffix letters to indicate their application. The total of all variations was 21. Three were compacts; Models 80, 82, and 84. The others, Models 83, 85, 86, 87 and 89 were consoles whose enclosures were offered as lowboys and highboys, some with doors, and one as a phone combination.

Analysis of the 80 series and its predecessors shows the continuity of the AK product line and its response to market conditions. Until 1931, the product line was targeted at the upper-middle segment of the total radio market. By then, however, customer preferences had changed enough to significantly reduce the business potential of that segment. AK responded by using the substantially less costly superheterodyne circuit and by offering the compact sets. (“Supers” were cheaper to produce because they did not require the difficult tracking-precision that characterized the four-resonator TRF). The style of the first compacts was established by other manufacturers, for example, Philco. AK's product designers followed the others, albeit interpreting richness into their designs.

The electrical and mechanical designs of the compacts reflect substantial cost reductions from the consoles, but no reduction in quality. The chassis was reduced in size (9"x14"), Fig. 52, and changed to a folded shape, instead of

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Fig. 52.
Model 84 Chassis

Photo: R. Williams
being a large stamping. Full advantage was taken of the cost advantages of the superheterodyne circuit. Model 80 was a no-frills, five-tube-plus-rectifier radio offered in a dressed cabinet. Model 82 added a control tube and made the cabinet a little more gothic in style. Model 84, Fig. 53, used the same circuit as Model 80 with a plain version of the cabinet from Model 82.

The large chassis that was used in all the consoles was based, mechanically, upon the stamped chassis that was introduced for the third version of Model 60. The superheterodyne circuit of the 70 series, type H-2, was the electrical base for the series. The order of complexity (and the price) in the series of consoles followed the model numbers. Model 83 had six tubes and used a single type 47 output tube. Model 85 added an automatic volume control tube, and Model 86 went further with a radio-frequency amplifier. Model 87 provided pushpull type 47s in the output but deleted the control tube. Model 89, Fig. 54, did it all: RF amplifier, IF amplifier, two detectors and their oscillator, low level AF amplifier, automatic volume control, pushpull-pentode output, and a rectifier.

In the 80 series, AK introduced what was, for his product line, a brand-new concept, the auto radio. It was identified as Model 81. The circuit was a seven-tube TRF, including a volume-control tube, using the newly introduced series of six-volt heater tubes, types 36, 37, and 38. Type 36 was a tetrode used for the three radio-frequency amplifiers. Type 37 was a triode. It was used in two places; the detector, and the control tube. Two type-38 pentodes were used in a pushpull-output circuit. The auto radio was powered by A, B and C batteries carried in a separate container. The heaters and the speaker field were powered from the six-volt auto battery.

Model 84 was the most popular of the compacts, and, because of the reduced sales of consoles as compared to compacts, the most popular set in the 80 series. Model 84 pointed the way to the future, but history has indicated that it
was not heartily welcomed by AK. Meeting the new market at the levels that had characterized the company for the past several years meant a very large, uncomfortable change in the way business had to be done.

THE 90 SERIES

By the middle of 1932, business conditions in the United States were depressed enough to change the radio market from the crush of credulous fans in the middle twenties to a highly discriminating audience that balanced finances against the appeal of a new radio set. Manufacturers realized that they had to appeal very strongly to potential buyers. One way was by the introduction of more new models than were offered in the annual campaign at the holiday season. AK’s mid-year appeal in 1932 was the group of radios that made up the 90 series. These were very similar to those in the 80 series, and corresponded in Model number with certain exceptions; Console Models 83, 87 and Compact Model 84 were dropped and Console Model 85 became Model 94.

A new feature was offered in Model 93, Fig. 55, a short-wave tuner. This was a four-tube unit made up of a mixer, a local oscillator, one stage of IF amplification, and a rectifier. The tuner made three short-wave bands available at a converted frequency of one MHz, to which the main receiver was to be tuned.

The top consoles in the line, Models 96 and 99, were modified from their earlier counterparts by the addition of a tuning indicator. It was a glow tube
connected in the plate supply circuit for the RF and IF amplifiers. When first identified, it was called a “Neon Tuning Light.” The sales potential of the new indicator was not missed by AK’s marketing people. They set up a national contest with a first prize of $1000 to select a name for the new AK feature. The name that became the advertising keyword was “Tonebeam”.

Not all of the earlier variations were carried into the 90 series. The 25-Hz power-transformer substitution (suffix F) was available for all compacts and consoles, but the battery and the direct-current variants (suffixes Q and D) were not updated. The auto radio, Model 91, was redesigned as a superheterodyne. It had nine tubes, included AVC, was offered in three configurations to accommodate different installations, but still used batteries for its B and C sources. With the auto radio becoming a superheterodyne, AK took maximum advantage of a reliable, conservative manufacturing and engineering base for his company. The circuit was standard and it was very easy to add and remove features like push-pull or single-ended output. Three lines of chassis fabrication had been established: the auto radio, the compact (9”x14”), and the console (12”x21”). The big changes that had to follow the 90 series were market-based, and were in the area AK liked least, enclosure appearance. Wooden cabinets and dependence on cabinet suppliers were not his favorite concerns. It appears to the author that the elements of the business that AK found most rewarding to his creative talents were reduced to near-routine and that, consequently, his enthusiasm was threatened.

RECEIVERS WITH THREE-DIGIT MODEL NUMBERS

In studying AK receiver production, the idea recurs that the Company’s life can be visualized in two periods. The first period seems to have ended in 1932, and has been described in these articles as Development. The second period seems to have been characterized by Maturity (in a business sense) and went from 1932 to the cessation of production in 1936. A very strong indication for this idea was the way the chassis developed from the panels in the mahogany sets, embraced the metal cabinets, became a very large structure (for radio sets), and then after 1932 was only resized downward. Another was the way that the appearance of the sets changed in going from the Open Sets, through the Mahogany and Metal Boxes, to the Compacts and Consoles in only ten
years. After 1932, styling seemed static. Still another was the change in service literature. It went from none for the early sets, through complete texts in the late twenties, to sketchy supplements issued in the later period. Future studies, hopefully inspired by these articles, may find that the strongest evidence for the two periods was the radio market itself, particularly as it changed in the depression. The story of the mature period should be told differently than the way that has been used for the development period. Some suggestions have been included in the following quick review.

A technical change that also occurred in 1932 has frustrated servicemen (and AK collectors) ever since. During the development period there had been strong, although not exact, correspondence between the first digit of the model number and the year of manufacture, but the sets made during the mature period no longer used that system. Three digits were used to identify all the sets made after late 1932, but the assignment of the first digit did not appear to be systematic. The third digit of the model number was used to state the number of tubes in the receiver. For sets having ten or more tubes the last two digits were the tube-count identifiers. Consoles were sometimes identified by using a suffix letter, and the earlier power-source suffixes were continued with their original meanings. It seems that the convenience of identifying years was traded for the ease (sales advantage?) of identifying tubes. The author has tried to correlate the first and second digits of the model numbers to advancing time (production year) without success. Since the early system has shown itself to have been effective, and the three-digit was faintly chaotic, the author has difficulty avoiding the idea that this too marks a difference between the development and maturity periods.

Because there were more than 165 similar receivers manufactured between late 1932 and 1936, a story of their minor differences far exceeds the purpose and scope of this article. Up to 1932 the AK story has been told by reviewing the year-by-year developments, but when this method of portrayal was tried for the three-digit series, the rendering was dull and unsatisfactory. The story of the receivers of the mature period might be better told by relating their characteristics and the market conditions at the time of their introductions, in a form suited to graphic presentation. As an example, the circuit for all three-digit series was the same superheterodyne used in the 80 and 90 series, with variations such as the number of amplifier stages and application of newer tubes as they became available. The correlation of these features seems stronger to marketing advantage and pricing than to technical development.

Another aspect of the mature period was the mechanical story; chassis sizes and dials. The development of the big chassis and its continued use has told much about the development period, but for the mature phase when smaller, less-expensive chassis were introduced, a chart of sizes and applications would provide a better basis for understanding the business. Fig. 56 pictures the radio considered to be the biggest (and best), Model 812, sold in 1933. Fig. 57 shows its 12"x21" chassis. For comparison Fig. 58 shows one of the smallest sets, Model 275, an A.C./D.C. receiver from the 1934 season. In Fig. 59 its 5"x10" chassis is shown. The problem of relating the characteristics of all the sets becomes clear when it is remembered that there were 165 between these two.
Fig. 56.
Model 812 Console

Photo: Alan Douglas

Fig. 57. Model 812 Chassis

Photo: Alan Douglas
Most of the radios built during the mature period were fitted with airplane dials. The earlier dials were 3” in diameter, and quite plain, but later sets were equipped with larger dials that lit with different colors to indicate the wave bands selected by the listener. A story is told that AK particularly disliked the airplane dials because he felt that the listener sitting in his chair should be able to see the dial setting, and that only the fan dials met that requirement. A tabulation of the sets that used window, fan, and airplane dials along with the chassis and the enclosure date for each set might be helpful to collectors in recognizing the breadth of the product line manufactured during the mature period.

Console styles changed very little in the early thirties. The biggest change was doing away with the console legs in favor of a full-height columnar motif. Changes in the compacts were a little more apparent, but in the very conservative AK line, they were small. The biggest change was going from the rounded top, that had started with the gothic arch in 1932, to the flat tops that came out in 1933 and were produced through the entire period. The cabinet story is almost a description-of-reuse based on slight circuit or tube variations, and responsive to the price-conscious market. The clear development progress that characterized the early period was no longer apparent with the three-digit series.
CONCLUSION

The reflections that come to us from the record, from the recollections of AK's employees, from descriptions sketched by close acquaintances and family, and from the technical chronology provided by his radios, tell of an outstanding early-twentieth-century manufacturer. The factory floor with its people, its product flow and its potential for increased business appears to have been a living reality to AK. He was interested in his employees, concerned with their well-being and fair in his treatment of them, but not indulgent. He set high standards for himself and expected his organization and the people around him to live up to his standards. He was very aware of his personal and commercial images, diligently protecting both by avoiding publicity about himself and his family, and by hewing carefully to the business standards of his time. Near the close of manufacturing operations in 1936, a group of his technical, marketing and manufacturing people approached AK with the idea of buying the Company and independently continuing in the radio-manufacturing business. He refused their offer, giving the reason that he could not sell his name because he could not be sure of its preservation.

The remarkable styling of the AK radio lines through the twenties illustrates the interplay of the man's strong creative personality with the evolving radio market. Company growth through the twenties and the first two years of the thirties attest to AK's acuity and resilience in shaping both the product and the market. The next two years can be read in two antithetic ways. The first (which the author rejects) suggests that AK backed away from the business and in 1936 gave up when the unions made image-demeaning demands. The flaw in this thesis is that AK had solved problems, far larger than those resulting from accommodating the mid-thirties changes in labor relations. Several former employees, in being interviewed, did not attribute the factory closedown to labor trouble, but to decreased markets.

The second thesis suggests that the same acuity, with which AK perceived the growth potential that resulted in his becoming the world's leading radio manufacturer, signalled the major changes that were coming in making and selling high-production radio sets. Midgets and medium-sized table models had virtually eliminated high-priced consoles. The market (in dollar volume) had decreased substantially and could not be expected to provide even moderate loading of the company's facilities, much less keeping it going at its former level. Radios changed from substantial (comfortable) furniture to gadgetry (treasure chest), with the result that the distribution and selling part of the business moved from conservative, old-line furniture stores to bargain, appliance vendors. Because radio marketing and production changed so drastically, AK recognized that continuance was really the building of a new business.

The political atmosphere of the middle thirties was hardly friendly to resolute, independent capitalists. AK had been struck from that mold and was, consequently, unwilling to accept what he felt was governmental regulation of his life (the Company). With four cycles of eminent business success, he decided not to go around again. Interestingly, the record indicates that AK (virtually alone) did not reinvest the returns earned in the twenties to keep going, only
to lose out later (Freed-Eisemann, Grebe). Instead, he chose to liquidate the factory and its tool while retaining the Company’s good name and his personal fortune. Much of the charitable work done by the Company, to this day, owes its continuance to AK’s choice to leave the radio business.

Shortly after the factory closed in late 1936, AK left the Philadelphia area to make his home in California. He settled in Belair (an affluent suburb of Los Angeles) where he was able to enjoy some of the pleasures that he had set aside during his business years. In the succeeding decade, AK earned a small reputation as a party-giver in the style of the movie-greats, but that was the extent of his public interaction. Until his death in 1949 AK spent his time quietly, away from politics and industry. His activities included furthering his appreciation of automobiles and his interest in boats.

AK’s need for privacy, and his reluctance to treat his radios as important historical artifacts, have left only the sketchiest picture of the man and his life. As the perspective offered by the passage of time grows, it becomes ever clearer that Arthur Atwater Kent was one of the great figures of the twentieth century. Perhaps these articles about AK and his achievements will help to uncover more material about him. Let us try, as historians, to be as effective in educating his story as he was in bringing AK radios to the twentieth-century world.

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**Ralph O. Williams**

Born in Nov. 1920, coincident with KDKA’s first broadcast, Ralph attended high school in N.J., followed by Cooper Union College. When WW II intervened, he studied radar, and after serving as a radar officer in China, he completed college at Northeastern University in Boston. After graduating in 1947, he joined General Electric and worked in varied aspects of radio engineering. He developed an interest in the history of the radio art, and after a 1965 move to Philadelphia, he concentrated his efforts on the historical material of RCA and Atwater Kent.

He joined the AWA, and through association and with the encouragement of other collectors he rapidly built a collection of Atwater Kent radio artifacts. He obtained a master’s degree in engineering science; his thesis was on the information-processing efficiency of the Morse telegraph code. After retiring from G.E. in 1980, Ralph moved to Orient, N.Y., on the northeastern end of Long Island, where he and Elmor and his excellent collection of Atwater Kent material reside in an historic house more than 300 years old.
PROGRAM TRANSMISSION
AND THE EARLY RADIO NETWORKS

Ludwell A. Sibley, KB2EVN
Flemington, N.J.

INTRODUCTION

The landline transmission facilities that once tied broadcast stations into national networks are mostly gone now, replaced by satellite program distribution. Network radio itself is hardly the same business today. But between the mid-Twenties and the late Sixties the networks were something of a technical marvel.

Local wire channels were used, almost from the start of broadcasting, to bring in remote pickups over short distances. Longer circuits had proven technically suitable for nonradio use, for example, in the ceremonies on Armistice Day in 1921. On that occasion, President Harding, dedicating the Tomb of the Unknown Soldier at Arlington National Cemetery, spoke to audiences in New York and San Francisco. His speech passed through a three-point transcontinental network that fed early-design public-address systems.

As radio broadcasting emerged over the next few years, it became apparent that long remote program feeds and "chain" operation of multiple stations would be highly desirable. Such operations would both enrich programming and spread the high costs of live production over many stations. It became clear that national audio facilities offering wide frequency response and low noise, i.e., of broadcast quality, would be a permanent necessity.

The line facilities for network operation were supplied by both the Bell System and the telegraph companies. This occurred in part because of early reluctance on the part of the AT&T Company to furnish circuits to members of the Radio Group (RCA, GE, and Westinghouse) in danger of weakening patent rights that AT&T reserved to itself. Only when the AT&T broadcasting stations WEAF and WCAP were sold to RCA in 1926 and NBC was created was this issue settled.

EVENTS IN NETWORK HISTORY

The history of early network radio and the various "firsts" that took place can best be outlined in chronological form. The following events give an idea of progress that occurred in only a few years, as taken from contemporary sources.1 2

January 2, 1921. Local remote broadcasts begin: Westinghouse station KDKA in Pittsburgh carries the first remote pickup, from the Calvary Baptist
Church. Facility is a telephone-company line. Follow-up events carried by the same station include an address by Herbert Hoover, about to become Secretary of Commerce, from the Duquesne Club on January 15; the first broadcast boxing match, on April 11, from Motor Square Gardens in Pittsburgh; the Davis Cup tennis match on August 4-6; and a National League baseball game on August 5.

October 8, 1922. AT&T’s station WEAF in New York carries the Princeton-Chicago football game from Stagg Field in Chicago. Succeeding games in the same season include Yale-Brown, from the Yale Bowl in New Haven, and Princeton-Harvard, from Cambridge, all via Bell facilities.

Late 1922. RCA’s WJZ operation tries feeding its existing transmitter in Newark from new studios in New York, using a leased Western Union cable pair. The circuit is initially troubled by substantial noise and telegraph crossfire. The new studios officially open on May 16, 1923.

November 17, 1922. The first Presidential remote: Harding speaks at Madison Square Garden in New York, with radio coverage over WJZ via W. U. cable.

January 2, 1923. The initial use of common programming over two transmitters: WEAF feeds a one-time demonstration program to WNAC in Boston over AT&T facilities.

June 7, 1923. Another network demonstration: a feed from the National Electric Light Association convention at Carnegie Hall, New York, via WEAF to WGY at Schenectady, KDKA, and KYW, then in Chicago; over telephone lines.

June 21, 1923. The first Presidential event via Bell lines: Harding speaking from the Coliseum at St. Louis over WEAF. Topic: the World Court.

June 22, 1923. A sequel to the previous day: President Harding talking from the Convention Hall in Kansas City on “Transportation Problems.” Importance placed by AT&T on circuit reliability results in use of dual-fed diverse-routed lines to New York: one via Omaha, Davenport, Chicago, Pittsburgh, and Harrisburg; the other through St. Louis, Terre Haute, Pittsburgh, and Philadelphia. Circuits included both a voice coordination line and a Morse order wire.²

July 1, 1923. The first regular network broadcast: WMAF, owned by Colonel E. H. R. Green on his estate at South Dartmouth, Mass., begins taking programs from WEAF via an AT&T line equalized for five kHz. WMAF is a seasonal operation; network operation continues until September 30. (The first permanent network connection to an independently owned station is from WEAF to WJAR in Providence, on October 19.)

July 7, 1923. WCAP, built by the Chesapeake and Potomac Telephone Company at Washington, opens with a program from WEAF.

December 11, 1923. The WJZ organization begins feeding WGY over W. U. wires; later extending to WSYR in Syracuse, and, by the end of 1924, to WRC in Washington via Postal Telegraph Company facilities. The WJZ network reaches WBZ in Boston in early 1925.
February 8, 1924. The first transcontinental broadcast: a Telco demonstration connecting WEAF with WCAP in Washington, WJAR, WMAQ in Chicago, KPO in San Francisco, KLX in Oakland, and, via the new Key West-Cuba cable, PWX in Havana. The circuit is two-way: General John J. Carty, chief engineer of AT&T, performs a roll-call of all the points on the network from Chicago.

June 6, 1924. The Democratic National Convention in New York is carried on the WEAF network of 17 stations as far west as Kansas City (WDAF) and as far south as Atlanta (WSB).

January 1, 1925. First U.S.-Canadian feed: CNRO in Ottawa is added to the WEAF network.

March 4, 1925. The WEAF network broadcasts the inauguration of President Coolidge on 21 stations.

December 23, 1925. General Electric’s freshly organized New York State Network (described below) reaches WHAM in Rochester, supplementing WGY and WFBL in Syracuse, and preceding WMAK in Buffalo.

December 31, 1925. The WEAF “Red” network now contains 26 stations, as far west as KSD in St. Louis.

November 1, 1926. The National Broadcasting Company is formed by sale of AT&T’s Broadcasting Company of America (owner of WEAF). WEAF and WJZ network activities come under common control.

December 31, 1926. The WJZ (Blue) network is disconnected from telegraph lines and moved to AT&T circuits, joining the Red network. NBC facilities now total 4800 miles of line. (The color designations are purely internal, being used only on circuit-layout maps. They become public much later.)

January 1, 1927. NBC runs the first transcontinental remote, the Rose Bowl game from Pasadena.

September 18, 1927. CBS opens as the Columbia Phonograph Broadcasting System. Initial program features the Metropolitan Opera Company. Schedule calls for supplying 16 affiliates with ten hours of programs per week from studios rented from WOR in New York. The phonograph company, having bought the rights of the United Independent Broadcasters, sells them back within three months.  

November 5, 1928. Evening before the 1928 presidential election: originations from Palo Alto, New York, Little Rock, and Pittsburgh are carried on 85 stations. Broadcast organizations include a special network set up by the Democratic National Committee.

December 23, 1928. The first permanent transcontinental connection: NBC joins its Pacific Coast network with the east. NBC’s total: 56 stations on 10,000 miles of line.

March 4, 1929. The inauguration of President Hoover is carried on 118 stations.

The national networks that developed were, of course, based on wire lines.
It was hoped at the start that short-wave radio could be used to distribute programming instead. In particular, the Westinghouse-owned operation at KDKA experimented with program distribution to outlying stations on 3200 kHz beginning late in 1923. Receiving stations in the experimental network included WBZ, KDPM in Cleveland, and KFKX in Hastings, Nebraska. While the results seemed promising at the time, the stability and reliability of wireline transmission won out despite higher cost. This held true even after off-the-air relaying of FM program feeds became possible.

THE NEW YORK STATE NETWORK

While AT&T was clearly the major source of network transmission facilities, the chronology above shows that the telegraph companies played a role as well. General Electric’s New York State Network provided a sizable amount of programming during the Twenties. Based on wires leased from Postal Telegraph, this layout connected WGY with WFBL, WHAM, and WMAK. The telegraph company furnished only the “bare” facilities; the necessary equalizing amplifiers were GE-designed and -built. The network began operation in mid-1925 and lasted into the early Thirties. WGY was normally the originating station, but the design of the amplifiers let any station transmit to all the others by manual reversal of direction. There were also occasional feeds to/from WJZ and WIBX in Utica. Much of the programming interchanged among the stations was live music from any of the four main cities. Before too long, the stations had their choice of feeds from the state network or the national ones: WGY from NBC Red, WFBL and WMAK from CBS, WHAM from NBC Blue.

While one would expect that the Bell companies, being more skilled at audio transmission than their telegraph cousins, would have normally provided better service, the Postal line apparently performed well and reliably. The absence of other voice-frequency circuits on the wire line allowed the use of unusually high audio levels to limit the effects of noise. The line was simultaneously used for a Morse order wire among the radio stations. The Morse line operated on a ground-return “phantom” (simplex) basis, using battery fed west from Schenectady. This was a sizable divergence from Bell practice, which used separate telegraph facilities to avoid any danger of “crossfire” into the program material.

COLOR-CODING THE NETWORKS

Each of the networks was traditionally designated by a color. As mentioned previously, “Red” was the original NBC layout. “Blue” was the second NBC linkup. This custom originated with the color of the pencil used to show routings on circuit-layout maps and continued with the use of colored designation strips on jack fields associated with network equipment. As the result of an FCC investigation begun in 1938 into network broadcasting, the Blue Network was sold in 1943 to become the American Broadcasting Company. The other colors are not as widely known. CBS was “Purple,” “Orange”
Fig. 1. The national Bell System program networks, 1929.
designated the NBC Pacific Coast operation, which by 1929 comprised eight stations between Los Angeles (KFI) and Spokane (KHQ). It was absorbed into the Red and Blue networks when they were expanded in 1936. "Brown" was assigned to the Don Lee network, which originally comprised KFRC (San Francisco), KMJ (Fresno), and KHJ (Los Angeles). Don Lee added KDB (Santa Barbara) and KGB (San Diego) before merging with the Mutual Broadcasting System in 1936. Mutual, formed in 1934, was "Gold." "White" covered a chain called PPA, based in New York, which fed 21 outlets for one hour a week during the late Twenties. There was also an eight-station "Green" hookup in 1929 that originated outside of New York. Its identity is unclear: called "ABC," it cannot have been today's ABC. When the Voice of America began using transcontinental feeds from its studios in Washington to the transmitter sites at Dixon and Delano, California, the mini-network was labeled "Bronze."

**A 1929 SNAPSHOT**

Figures 1 and 2 are a composite of published material showing the permanent and recurring program networks provided by the Bell System as of early

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Fig. 2. The Bell System program networks in the northeastern United States, 1929.
1929.\textsuperscript{10,11} Compared to the more mature layout of later years, the facilities are quite sparse, with numerous states having no network station at all. The drawings include the Blue Network "round-robin" circuit from New York to Chicago and back. In particular, New York fed to the northwest, delivering service to Rochester (WHAM). Passing west through Buffalo, the circuit looped into Canada before reaching Detroit (WJR) and then Chicago. The latter point fed local NBC affiliates (WGN, KYW, et al.) and passed the signal southeast through Indianapolis to Cincinnati (WLW), then back via Pittsburgh (KDKA) to New York. Red Network facilities could be looped in a similar fashion. With this arrangement, New York and Chicago could readily originate to all points on either network without switching by AT&T or the associated switching charges.

Facilities were scarce in these early years of fast growth. For example, only one program could be supplied to New Orleans from Birmingham. WDSU could take a CBS feed, or WSMB could receive NBC, but not both simultaneously. This particular deficiency was corrected not far into 1929.

Figures 1 and 2 do not attempt to show specific networks, NBC Red vs. NBC Blue vs. CBS. The reason is that facilities were assigned flexibly, day to day and hour to hour, according to the networks' orders and the stations' schedules. As a result, many facilities on the figures were not associated with a particular chain.

There were some feeds into Canada: as mentioned in the chronology, the Red Network supplied a station in Ottawa for a time. CBS provided some trans-border programming, as did Mutual and the Michigan Broadcasting Network in the Thirties.

VENTURES AND FAILURES

There were recurring attempts to form a third or fourth or fifth national network. The Amalgamated Broadcasting System was formed in 1933 by Ed Wynn, the comedian who also founded WNEW in New York. Amalgamated began as the Atlantic Seaboard Network,\textsuperscript{12} a group of six small stations between New York and Washington, all operating at 500 watts or less. It expanded operation in October, feeding 100 outlets via Western Union lines, then went bankrupt six weeks later. The American Broadcasting System (also not to be confused with ABC) began feeding 16 hours of programming a day to 18 stations between New York and St. Louis in late 1934. A "Transcontinental Broadcasting System" announced plans as of late 1939 to start operation in 1940. The Associated Broadcasting Corporation actually did get on the air in September, 1945. Further details as to the fates of these three attempts are lacking. The Liberty Broadcasting System, organized by the McLendon broadcasting family of Texas, went on the air in October, 1950. It initially supplied ten hours of programs a day to 240 affiliates, and lasted until May, 1952. These were all intended as national linkups; regional operations like the Intermountain Network were often more successful.
FACILITIES: AN EXPENSIVE BUSINESS

The growth of the radio networks called for substantial investment on the part of AT&T in two areas: the development of suitable wideband transmission equipment (equalizers, amplifiers, switching centers) at a time when electronics was still an infant art, and the construction of the actual copper facilities. AT&T had originally entered broadcasting with the idea of establishing "toll" radio stations (WEAF, WCAP). When it developed that show business was not a particularly good endeavor for a public utility, the corporate commitment changed to provision of transmission facilities. However, an echo of the original AT&T business plan could be detected in the early Thirties, long after the radio stations had been sold: corporate engineering references were still titled "Program Supply Practices." As for the substantial investment in facilities: even a short section of a network, for example the 585 miles of 165-mil wire from Omaha to Denver, required 255 tons of copper and 47,000 insulators. Preparing an existing wire pair for program use meant giving up the voice trunk that would otherwise use the line, removing the "phantom" arrangement that derived a third voice path from two wire pairs, taking off the two ground-return telegraph circuits that were normally present, and, often, giving up one channel of the three-channel "Type C" carrier telephone system that was widely used to obtain extra circuits. Thus program facilities were expensive indeed.

TRANSMISSION TECHNOLOGY

The first network activities used existing telephone circuits of narrow bandwidth, about 2500 Hz. Short-term networks were patched together at wireline testboards for the occasion. Experience soon showed the desirability of building permanent facilities of higher quality.

In the Twenties, a growing quantity of AT&T facilities east of Chicago or St. Louis were cables, whereas the plant to the west was predominantly open wire. The typical 19-gauge cable, with the then-latest type of loading coil intended for long-distance telephone transmission (44-millihiem inductors spliced into the cable at 6000-foot spacing, or "19H44" cable), was good for transmission up to about 4500 Hz over modest distances. This proved to be a workable bandwidth, being better than the typical broadcast receiver at the time or, for that matter, now. With special 3000-foot spacing of the coils ("19B44"), the frequency response could be extended to 5000 Hz. However, a cable design much more suitable for thousand-mile distances was introduced in 1930 by using 16-gauge pairs, lightly loaded with 22-mH coils at the "B" spacing. Termed "16B22," this design could be equalized nearly flat between 100 and 5000 Hz over distances of 2000 miles or more and, with care, could handle a range of 50 to 8000 Hz. It gave far less delay distortion than the heavier-loaded facilities, yet did require some delay equalization for long-distance use. Open wire could be equalized readily for 5-kHz or even 8-kHz use once suitable equipment was available. Figure 3 shows the typical
transmission losses, before equalization, for typical cable repeater sections of 50 miles and open-wire repeater spacings of 150 miles.

The line amplifiers used for program service advanced with the times. The first ones were simply Western Electric 44A1 telephone repeaters, the then-newest design, using two “V” (102D) and two “L” (101D) tubes. The circuit was slightly modified to give improved equalization. Around 1929 a specially designed program amplifier, the 12C, appeared on the scene. Using a 102F triode driving a 101F, it provided enough output to feed open-wire lines at high level. About 1938 a much-refined amplifier, the 14C, came into use. It was a push-pull, negative-feedback design with 310A and 311B pentodes. It was advanced enough to enjoy wide use up to the solid-state era.

This equipment was build rock-solid for reliability. It was bulky, too: the equipment for one network repeater—the amplifier, reversing circuits, gain and delay equalizers for two directions, plus a multipoint distribution bridge—occupied most of an 11-foot rack. Once installed and lined-up, it ran for years with only a rare tube replacement.

Transmission of 5-kHz audio was almost entirely on a “baseband” or audio-frequency basis until after World War II. It was possible to find program circuits on main open-wire lines throughout the West. Climbing a pole, a lineman could clip his test set onto a pair of wires on the top crossarm and encounter network audio miles from any town.

Multichannel carrier transmission on wire pairs, coaxial cable, and microwave radio became important during the Forties. To handle high-quality program service, special carrier terminals were developed that displaced two ordinary telephone channels (for 5-kHz transmission) or three channels (for 8-kHz). The filter-type single-sideband generator for 8-kHz service had to meet such stringent performance requirements that each filter used a total of 44 quartz crystals. Despite the technical availability of 8-kHz and even 15-kHz facilities, however, the commercial networks considered 5-kHz service to be a satisfactory balance between price and performance. Backbone portions of the major networks were 5-kHz, with some use of 3.5-kHz facilities on spurs into remote towns.

Fig. 3. Transmission losses - typical program facilities.
JOINT OPERATION: THE NETWORKS AND TELCO

The hour-to-hour operation of the networks required a means of coordination, as a unified national network often split into regional sections during specified hours, or might take a feed from an intermediate point. AT&T used a multipoint teletypewriter circuit to coordinate its regional program operating centers, originally Chicago, Cincinnati, and San Francisco, from the main center in New York. Morse wires extended from one of these offices to each program repeater point, to the network control points, and to every network affiliate station in its area. These wires were used to distribute the networks’ daily switching orders, and last-minute changes to those orders. Switching arrangements were provided so that an AT&T Long Lines technician in New York could reach any network station in the country. As of 1929, the telegraph order wires totaled 43,000 miles, while the full-time networks themselves involved only 28,200 miles. Radio engineers at local network outlets had to double as Morse operators, as did the telephone testboardmen who worked with them. Some typical Morse call signs were: AT&T network control at New York, NR; AT&T control at Chicago, CQ; WEAF studios at 195 Broadway, BY; WIP at Philadelphia, RF; KDKA, RW; WCAP, CA; WGY, GY; Princeton repeater station, PN; Harrisburg testroom, HB; and Washington testroom, W.15

As an example of how important telegraph coordination was to the operation of the networks, close examination of Figure 4, a photo of the New York

![Fig. 4. A portion of the program-apparatus layout in the Bell System New York Program Operating Center, as of January 15, 1929.](image)

_Photo: Reprinted with permission from the Bell System Technical Journal, © 1930, AT&T._
operating center NR,\textsuperscript{16} reveals a then-new Model 14 teletypewriter, plus 24 Morse sounders, each in its triangular resonator mounting. The Chicago center was no simpler. On a busy evening, the sound of all those telegraph circuits must have been impressive; yet skilled operators were able to sort out the individual stations on the wires by such means as the "fists" of the senders.

As the foregoing implies, Bell operating people were inseparable from the networks' own engineers in daily operation. In the pre-satellite era, transmission facilities were scarce and expensive, hence had to be used intensively. Technicians in the Telco (a commonly used jargon term for the telephone company) operating centers had to preset switches and carry out switch orders to bring in remote feeds and perform region splits, often by listening for the network cue. A missed cue brought the wrath of the network master controller upon them, and might require a rebate of switching charges as well. They performed continuous monitoring, both for quality checking and to detect the "good night" at the end of a remote broadcast. They stood by to perform make-good patches. When, say, an ice storm brought open-wire lines down, it might be necessary to reroute through a thousand miles of spare facilities to restore the failed section.

In the Twenties, the gain of a line amplifier varied with time and with changing battery voltage. The transmission loss of wire lines changed with the weather. So it was originally necessary to do a daily lineup of both gain and equalization. Each repeater station along the line had to make its adjustments before the network started the day's programs. As early as 1929, the total Telco operating force dedicated to program service was about 300 people nationwide, even though the networks then operated only about six hours a night. It was not difficult to justify such labor-intensive participation. The networks were part of "radio"; they were a highly visible national resource and carried a high-tech image with the public.

When network television became a reality after 1945, the sound channels that accompanied the video were carried over conventional program circuits. This was done for two reasons: if a failure occurred, at least part of the network held together until the video could be restored. Suitable diplexer devices for carrying the sound channel on the video circuit were yet to appear. This led to a special consideration for telephone circuit-layout people. Because the microwave video part of the network operated at nearly the speed of light (186,000 miles per second), while a sound circuit on 16B22 cable transmitted much slower (20,000 mi/sec), a difference in delay could build up over long distances. More than about 40 milliseconds difference can disturb the television viewer's perception of lip-sync. So the television networks were laid out carefully to control the difference in delay between the sight and sound channels. They made heavy use of carrier program facilities, which did provide high-velocity transmission. Only after diplexed sound appeared in the mid-Seventies did this consideration cease to be an issue.

In daily operation of the networks, it was often necessary to reverse the direction of a program circuit, either to put up a temporary circuit on spare facilities that normally operated in the opposite direction or to let a full-time
network originate from a point that usually just received a feed. Originally this required coordinated patching action at each repeater point along the line: repeater attendants would use patch cords to reverse the directions of the equalizers and amplifiers at their locations. During the Thirties reversing equipment was developed. By feeding a 130-volt direct current over the line wires, relays were operated that turned the next repeater point around and caused it to apply a fresh 130-volt current toward the next farther point. Thus, if CBS wanted to send a program from Washington to New York instead of receiving it, the studio in New York would release control of the circuit. Then Washington’s reversing current would turn the amplifier around at Baltimore... Baltimore would send current to reverse Elkton... Elkton would switch Philadelphia... and on through Princeton to New York. A coast-to-coast reversal could be done in only the time required for a station break. Reversals could be controlled by either Telco or the network.

The reversing arrangement used the earth as a return path for the DC control current, as did many telegraph circuits at the time. Both the reversing and the telegraph circuits were exposed to disruption caused by earth currents induced by magnetic storms. Big magnetic storms, like the major one in April, 1940, meant busy times for the network engineers and the Telco program technicians.

The mileage of Bell program-grade facilities grew in step with the broadcast industry. At the end of the Twenties the figure was 28,200 miles of full-time networks feeding 123 stations, plus a certain amount of spare for occasional use and service protection. The Depression choked off development of the long-distance telephone system but did not stop the networks’ growth: as of early 1936, radio mileage was up to 40,000 miles of full-time networks and another 20,000 for part-time use.\(^{17}\) By 1948 the total had exceeded 150,000 miles, and 1,000 stations, with about one-fourth of the total mileage derived from multichannel carrier systems instead of baseband transmission.\(^{14}\) The aggregate mileage peaked at somewhat more than twice the 1948 figure before declining in favor of satellites. To close the story: in April, 1988, AT&T filed with the Federal Communications Commission for authority to discontinue offering terrestrial program service, on grounds of sharply diminished demand.\(^{18}\) If granted, this action would bring the service to an end after 62 years.

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Ludwell A. Sibley

"Lud", as he is known to his friends, is a 13-year member of the A.W.A. An electrical engineer by training, he has a background in radar astronomy and broadcast technology, but his primary experience is as a telephone transmission engineer. He is interested heavily in the technical history of the telegraph, telephone and radio industries...but is not above collecting an occasional antique transistor or other flea-market prize.
AUDIO FREQUENCY CHARACTERISTICS IN EARLY BROADCASTING

Robert M. Morris, W2LV
Sparta, N.J.

In these days of "Hi-Fi" and rapidly advancing FM aural broadcasting service it might be of interest to recall and record some of the technical characteristics of broadcasting in the early twenties. This account will be from the vantage point of one who heard much of the early broadcasting in the eastern United States and who served as a member of the operating staff for WEAF of the A.T. & T. Co. I was especially fortunate, not only in being a member of this prominent pioneer broadcast organization, but also in being stationed at the WEAF transmitter located at 463 West St. in New York City. This location was initially that of the Engineering Department of Western Electric Co. which, in January, 1925, became the newly created Bell Telephone Laboratories. This provided an opportunity for frequent contact with the foremost telephone engineers of the middle twenties.

I believe it is an accepted fact that radio broadcasting was significantly stimulated in its development by the radio amateur of 1920. Following World War I, many amateurs built or otherwise obtained low-powered radio-telephone transmitters. Many of these were used to transmit occasional and sometimes scheduled concerts of phonograph music. As a result, the amateur radio operator of 1920 provided both the source of and the audience for the programs which sparked the tremendous public interest in radio broadcasting the following year. In 1920 and early 1921 the ads for equipment in radio magazines were directed to the radio amateur. Even such an item as the Westinghouse RA tuner was designed to provide "efficient telegraph and telephone reception over the amateur and normal ship wavelenth ranges."

In early 1921 the Department of Commerce served notice on amateur stations that transmission of music was not permitted, and that those wishing to engage in such activity must qualify for and obtain limited commercial licenses.

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for broadcasting. This was done by several amateurs, and they continued their programs with commercial call letters, and initially with the same equipment used on the amateur basis. At this same time other interests such as department stores, manufacturing companies, and newspapers, with considerably more money, became interested in radio broadcasting and enlisted the aid of knowledgeable amateurs in obtaining licenses and establishing the necessary transmitting equipment. Thus many of the earliest broadcasting stations came into existence, either directly from—or with the cooperation of—the amateur service and its radio-telephone technology.

In view of the foregoing, if one wishes to make the point that early broadcast stations were lacking in uniformity of performance and technical quality, there would, I am sure, be ample confirmation. It has been stated that the combination of acoustically recorded and reproduced phonograph records, microphones of restricted frequency range and high carbon noise level, together with poor studio acoustics, created distortion difficult to conceive of today.

Simultaneously, however, there was developing within the "Radio Group" (A.T. & T., General Electric, Westinghouse, and RCA) a considerable interest in this new service called radio broadcasting. These companies employed engineers who were highly skilled in the radio and telephone arts. The telephone company was especially interested since they regarded broadcasting as a form of telephony and therefore directly related to their main business. They had, in fact, been developing radio telephony for communication with ships in 1920 and 1921. They accordingly initiated through Western Electric the design of the first commercial broadcast transmitter and other related equipment. The resulting transmitter, a 500-watt unit known as the 1A (see Fig. 1), was subsequently used not only by the telephone company stations WBAY, WEAF, and WCAP but by many other pioneer broadcast stations of 1922 and 1923. It is the quality and characteristics of such stations and equipment that I shall review principally in this discussion, since these stations set standards that others were quick to recognize and attempt to emulate.

There were two principles of audio transmission invariably used by the telephone company in its broadcast plant which I believe accounted in large measure for the technical superiority of its stations. These were, first, the matching of impedance in interconnected equipment and, second, the insistence upon uniform or flat frequency response of all units of equipment and of the overall system.

Frequency characteristics of radio transmitters and of key studio amplifiers were checked daily over the range of 100 to 5000 cycles per second. Other factors, of course, contributed to improved quality; examples were the use throughout the plant of balanced circuits to avoid hum and crosstalk, and the use of the volume indicator for checking and adjusting audio levels to prevent overloading of amplifiers, which would cause distortion. These principles and their importance were not known by those not skilled in the telephone art, and this fact, I am sure, accounts for the sometimes wide difference in quality of those stations equipped by the telephone company and those using composite equipment.
Fig. 1. The first commercial broadcast transmitter, the Western Electric 1A, 1922.
A broadcasting station of 1922 with Western Electric equipment would include the following major items of apparatus:

1 to 3 double-button carbon microphones (369W or 373W)
A mixer, if more than one microphone was used
8A studio amplifier
518B volume indicator
18B monitoring amplifier and 7A horn type loudspeaker
1A 500-watt transmitter
4B 600-meter monitor receiver
Antenna system

If the transmitter was not at the same location as the studio, an interconnecting wire line with a 1A equalizer would be added.

The frequency-response characteristic of such a facility, minus the microphone, as measured by D.K. Martin of the Development and Research Department of A.T. & T. in 1923, is shown in Fig. 2A. Note that the ordinate is given in “Miles of Standard Cable.” This unit of transmission measurement was used until about 1924 when it was replaced by the “Transmission Unit” or TU. The Mile and the TU were almost identical in value, the TU being equal to 0.95 Miles. The TU, in turn, was renamed the “Decibel” about three years later.

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Fig. 2. Frequency response characteristics of various elements of the system. Refer to text for details.
The facilities whose characteristic is given included an 8A studio amplifier used by WEAF at 195 Broadway, an equalized cable about 1 1/2 miles in length from there to 24 Walker St., and a 500-watt transmitter originally used at station WBAY, identical to the one then used by WEAF at 463 West St. This characteristic, with a slight adjustment of the equalizer, would meet present-day FCC requirements for AM broadcasting. The frequency characteristic of the WEAF transmitter used in 1926, a 5-kW unit, together with the equalized line from 195 Broadway to 463 West St., is shown in Fig. 2B.

The only circuit element missing from these measurements is the double-button microphone. These mikes (see Fig. 3) were stated to have a uniform response over the range of 30 to 7000 cycles per second. I know of only one objective acoustic measurement of these early microphones; this is included in a paper by Martin and Fletcher in 1924, and is shown in Fig. 2C. From subsequent comparisons with condenser microphones of known characteristics, I am sure they were generally quite satisfactory in response over the 100 to 5000-cycle range. Their principal limitation was in the signal-to-noise ratio, which I believe was seldom better than about 40 dB, and in distortion on high-level, low-frequency sounds.

If the program originated at a point outside the studio, another studio amplifier at the remote point and a specially equalized and balanced telephone circuit were involved. Such lines, usually less than 10 miles in length, could always be equalized to within 2 TU (dB) over the 100 to 5000-cycle range. The quality of a remote pickup was therefore, to all intents and purposes, identical to that from the studio. Fig. 4 shows an early portable field amplifier used by
Station WJZ. (It is obviously portable because it has handles.) A similarly heavy oak box was used by WEAF to house an 8A amplifier and volume indicator, with batteries.

It is interesting to note that the telephone company referred to such operations outside the studio as “wire telephony as an adjunct to radio broadcasting”, and the official levels preferred the use of this terminology. Refer to Fig. 5. One of the WEAF operators, G. E. Stewart, decided this was much too clumsy for operational use and suggested it be called “Nemo”; remote or outside pickups are still commonly referred to as “Nemos.”

If the remote pickup originated in another city or if the radio transmitter involved was that of another station, and a part of a network, the use of specially engineered long lines was involved, contributing additional problems. One was a decrease in signal-to-noise ratio due to line hum from power line induction. Another was a slight reduction in audio-frequency range (usually a sharp cutoff at about 4400 cycles), and a third was a “tweet” effect due to what later was called envelope-delay distortion. This is by way of saying that some frequencies of the audio spectrum traveled over the line faster than others, and
with a long circuit the difference in time was sufficient to be quite audible. Fig. 6 shows the measured time of transmission and equivalent velocities for various frequencies on a circuit from New York City to Chicago and return, a total length of 2141 miles. This effect, of course, was recognized and later corrected by phase equalizers, but it was a rather obvious problem with early network broadcasting.

The antennas and ground systems of early broadcast stations were quite varied and generally inefficient by modern standards. Their inefficiency did not materially affect the quality of reception, but it did reduce the range served by the station and reduced the received signal-to-noise ratio. The stronger stations were usually the more popular for this reason. Station WABY, the first station of the A.T. & T. Co., was a classic example of a poor radiating system. The building at 24 Walker St. was high enough to effectively insulate the antenna system from ground for the 360-meter wavelength, and after less than a month’s operation at that location, the broadcasting activities were transferred to the station at 46 West St. (WEAF). It was several years before the importance of large radial ground systems and vertical radiators was fully recognized.

Let us turn now to the broadcast receiver and its problems. As was stated at the beginning of this paper, almost all of the earliest broadcasting was of, by, and for the radio amateur. The receivers used were usually the regenerative type, designed for receiving spark signals. Audition of received signals was usually by means of headphones, unless the amateur was unusually serious or affluent and had a Magnavox speaker. Sometimes a makeshift loudspeaker was created by applying a headphone to a phonograph horn.
Any loudspeaker of that period was seriously deficient in low-frequency response and generally was characterized as being "tinny". This was not the worst shortcoming, however. The receivers of 1921 usually had two stages of audio amplification with from 45 to 90 volts applied to the plates of the Moorhead valves or the RCA UV201 tubes. In any case, the maximum undistorted output of such an amplifier was probably about 30 milliwatts, and efforts to raise the volume to a useful room level resulted in extremely objectionable distortion, usually blamed on the loudspeaker. This, together with price considerations, caused crystal sets to enjoy considerable popularity, especially with those in close proximity to broadcast stations.

I believe that what this says is, that while the first broadcast stations varied widely in technical quality and performance, the receivers in use at the time varied even more widely. They were not designed for broadcast reception, and their performance, as compared with receivers made only five or six years later, was quite deficient. I believe it was only the seeming miracle of getting voices and music out of the air that caused the almost immediate public acceptance of this new potential service. There were estimated to be 500,000 receiving sets in the United States by the end of 1921.

The years 1922 and 1923 saw clearly the need for the design and manufacture of receiving sets specifically intended for the broadcasting service. This marked the beginning of a transition period for receivers, from those designed for amateur and commercial service, to those designed for broadcast reception by technically unskilled persons who desired to avail themselves of the programs which broadcasting had to offer.

This period lasted until early 1928. It was marked by a progression of developments such as new tubes requiring much less filament power (the WD11 and WD12, the 199 and 201A), the introduction of audio-amplifier
tubes with higher output power (the 112 and 171), and the advent of B-battery eliminator power supplies, capable not only of eliminating the repeated cost of B batteries, but also providing inexpensively and efficiently the higher voltage and current needed for higher undistorted audio output.

With these changes came also a multitude of loudspeakers, some bad, some fair. Most noteworthy of the new loudspeakers, for its time, was the Western Electric 540AW cone speaker. It was a substantial improvement over any existing speaker when it first appeared in 1924, and it became the standard broadcast monitoring speaker until it was superceded by the Rice-Kellogg dynamic speaker about three years later.

Another improvement brought about by Western Electric Engineering was the announcement of the Victor Orthophonic Phonograph, together with electrically—rather than acoustically—recorded records. This made possible the use of the same microphones and amplifiers in the recording studio that were used in broadcasting, and it resulted in greatly improved music quality of those stations using records.

Other changes in broadcasting also occurred at this time, with considerable effect on its overall development. The National Broadcasting Company was
organized in 1926 as a subsidiary of RCA to carry on the operations of RCA and A.T. & T. in the broadcast field. NBC set up new and expanded facilities in 1927, including a new 50-kW transmitter for WEAF, located at Bellmore, L.I. Station WJZ had made two moves, one in 1923 from Newark to Aeolian Hall in New York City, and another in 1925 when the transmitter was moved to a new “super-power” 40-kW plant at Bound Brook, N.J. Fig. 7 shows the modulator unit of this transmitter, while Fig. 8 shows the frequency characteristic of station WJZ after the consolidation with NBC in 1927.

Improved circuits of greater frequency range began to be available. In 1928 the circuit from the NBC studios at 711 5th Ave. to WEAF at Bellmore was changed to an H22 loaded-cable circuit with a frequency range to 7500 cycles instead of 5000. Similar improvements in studio facilities and increases in transmitter power were taking place at many other locations in the United States; progress was not limited to New York, even though most of the network programs originated there.

This transition period was also marked by a slow and seemingly reluctant change from the regenerative receiver with its sensitivity but highly variable and sometimes unpredictable characteristics, to receivers that would be easier for the unskilled to operate. These included, of course, the tuned RF, the neutrodyne, and the Armstrong superheterodyne.

The end of this period of transition came suddenly, and was marked by the announcement of tubes which could operate directly from alternating current, requiring no batteries, and of radio-frequency amplifier tubes equipped with a mysterious second grid, making neutralization unnecessary. Now the jigsaw puzzle began to fall into place. The band of frequencies and the allocation pattern for broadcast stations was becoming stabilized, and the desired characteristics for the performance and operation of broadcast receivers was generally understood and agreed upon. Loudspeakers of ample capacity were available, along with a variety of tubes which could deliver adequate undistorted output power. The receivers now had the necessary sensitivity and flexibility of design, with no requirement for power other than that supplied from the wall socket.
The result was that a wide variety of receivers having characteristics suitable for the broadcast service became available to the general public, with a quality and performance demonstrating a significant improvement over that of their predecessors. Undistorted audio output of two to ten watts was common, the dynamic loudspeaker with its improved—and sometimes accentuated—low-frequency response was very popular, and the superheterodyne circuit, with its uniform response over the complete tuning range, became widely accepted.
The response characteristics of representative receivers of 1928 and 1929, not including the loudspeaker, are shown in Figs. 9 to 11. These characteristics, which are flat within approximately 6 dB from 80 to 4000 cycles, would, I believe, be comparable—if not superior to—those of most AM broadcast receivers of 1969. Fig. 12 shows a characteristic taken of an RCA type 106 dynamic loudspeaker. It has a peak of 10 or 12 dB at 3000 cycles, but also exhibits good response down to about 60 cycles. This would not qualify for "Hi-Fi" performance, but it was a substantial step toward better audio quality in 1929.
This paper, originally prepared and presented in 1969, is published here essentially as it was originally given. The wording and terminology is as was commonly used and accepted in the nineteen sixties; cycles per second were not yet “Hertz”, and “Hi-Fi” was as understood at that time, and had no reference to compact disks or digital audio.

In 1927, the weakest link in the aural-broadcast system was usually the loudspeaker. When NBC moved to new studios at 711 Fifth Ave., a variety of monitor loudspeakers was tried in the studio-control booths. This was a mistake. Directors tended to prefer a speaker in one control booth and dislike the others, and the opinions were all different. With tact and persuasion, the type RCA 106 speaker replaced the others, and when Radio City studios were planned a new double-voice coil speaker was designed with a frequency response from 60 to 8000 cycles per second; this was used at all points.

The 1969 presentation was supplemented by some carefully prepared recordings representative of the variations in audio quality which have been described, accounting for the rather abrupt ending of the paper in its written form. Unfortunately it is not possible to present those aural recordings here.

This raises an interesting point relating to museums and collections of communications artifacts. If one has, or has access to, equipment in good condition as used in early broadcasting, including microphones, amplifiers, a radio transmitter, radio receivers, loudspeakers and phonograph and aural recordings, he can re-establish an operating system which should be capable of duplicating the results described here. This is one advantage possessed by artifacts used as a supplement to written history, since they can present history in a manner not requiring interpretation by an intermediary. Both written history and artifacts have their place, and can contribute to a better understanding of the past.

Robert M. Morris
Bob retired from the American Broadcasting Co. in 1967, joined the A.W.A. the same year and attended the first annual conference at the Smithsonian in Washington in 1968. First licensed as 2CQZ in 1922, he became 2LV in 1926. He entered broadcasting in 1924 as an engineering intern and became development engineer for NBC in 1927, participating in the development of television, FM, transcription recording, and the VU meter. Bob is a Fellow and Life member of the Institute of Electrical and Electronic Engineers, and has a strong interest in preserving radio history and the artifacts of significance in the development of wireless communications.
A.C. SUPPLY FOR RADIO RECEIVERS —
HOW THE LOWELL & DUNMORE PATENTS
(ALMOST) CHANGED THE INDUSTRY

Alan Douglas
Pocasset, Mass.

THE ORIGINAL INVENTION

They were not the most important patents of the 1920s, nor, in the end, the most lucrative. But toward the end of the decade it looked as if they would put a stranglehold on the radio industry; since they covered the basic idea of an AC-operated power supply, few radios could be built without them. Whether the power supply was built in, or external (as in a B-battery eliminator) did not matter. And they caused an upheaval in government patent policy. For many years, federal employees had been allowed to patent inventions in their own names, but when inventions developed with government facilities, on government time, and patented with government funds became potentially worth millions of dollars, the government sued to get them back from the owners, Percival Lowell and Francis Dunmore.

Fig. 1. P.D. Lowell poses with his first model on June 16, 1922.
Photo: Bureau of Standards, courtesy of W.F. Snyder.
Fig. 2. 1,455,141 was the basic Lowell & Dunmore patent, and the first to issue. It covered any radio set powered by AC. Claim 3 is typical: “In an apparatus for the reception of radio signals the combination of a source of signal energy, means for amplifying said signal energy at radio frequencies, means for rectifying said energy, means for amplifying said energy at audio frequencies, a source of alternating current for supplying power to said amplifying means and separate means connected to each of said amplifying and rectifying means for eliminating the hum of said alternating current in the said apparatus.”
Who were these masked men? Radio engineers at the Bureau of Standards in Washington. Percival D. Lowell had been there since Feb. 4, 1913, shortly after graduating from a Washington, DC high school. In ten years he had worked on a variety of problems, most recently submarine antennas, and was a member of Dunmore's research group assigned to aircraft radio. Francis W. Dunmore, born in Haverhill, Mass. in 1891, spent three summers as a commercial radio operator before receiving his B.S. from Penn. State College in 1915. After two years with GE in the student engineering course, and a year at Amrad, he joined the Bureau on Jan. 14, 1918, developing direction-finding gear and antennas, later specializing in radio-navigation and aircraft-landing equipment.

Dunmore, with some freedom to choose his projects, designed a remote-control relay receiver for torpedoes and aerial bombs for the Army Air Corps, one of 44 projects assigned to the Bureau in May, 1921. This was selective at both RF and AF and closed a relay contact when it received a particular signal. After building a conventional battery-powered design, on Aug. 3, 1921 Dunmore conceived the idea of operating his receiver from AC, and by Dec. 16 he had perfected his new arrangement. On Feb. 27, 1922 he filed for a patent whose most valuable feature was the obtaining of grid bias from a rectified and filtered AC source (1,635,117). Dunmore described his relay receivers in a paper read before the American Institute of Electrical Engineers.¹

Lowell, meanwhile, was involved with RF amplifiers, work that culminated in a Bureau publication.² He designed an iron-core RF transformer, and a circuit to utilize it, applying for patents on both on Sept. 9, 1921. By Nov., 1921, the Radio Instrument Company of Washington was advertising such amplifiers and transformers, and by the time the patents issued on Dec. 19, 1922 (1,439,562 & 1,439,563), Lowell had joined the company as chief engineer and assigned the two patents to it. He remained with the company for two years, before joining A.H. Grebe & Co.³

During the fall of 1921, both Lowell and Dunmore were familiar with AC operation of radio amplifiers. While they were officially members of the Bureau research group assigned to aircraft radio, not broadcast radio, they naturally considered applying their knowledge to broadcast reception. Working on their own initiative, though with Bureau equipment and on Bureau time, they got a broadcast-receiver circuit running from AC power by Dec. 10, 1921, applying for a patent on Mar. 27, 1922 (1,455,141). In addition, they built an audio-power amplifier and dynamic speaker that ran on AC by Jan. 25, 1922, filing a patent application on Mar. 21 (1,606,212).


Fig. 3. Lowell and Dunmore's original apparatus, obtained by the Smithsonian Institution from patent attorney John Brady.

*Photo: Smithsonian Institution/Elliot Sivowitch*
When Lowell wrote a technical paper on his device, the story was quickly picked up by several radio and electrical magazines and the Bureau was deluged with inquiries:

"Through an error, an incorrect statement was released to the press through the Department of Commerce Press Room regarding the amplifier developed by Mr. Lowell which uses 60-cycle alternating-current power supply for both filaments and plates. The publicity release stated that about May 1st the Bureau of Standards would have on sale for 5 cents a publication describing this

\[\text{Fig. 4. Lowell and Dunmore's two other patents were these, covering an audio power amplifier running from AC, and the method of obtaining grid bias from a rectified and filtered AC source.}\]

\[\text{4 Letter Circular 65 of May 10, 1922, then in its final form in the A.I.E.E. Journal in July (Vol. 41, pp. 488-490) and in the Scientific Papers (Vol. 18, pp. 345-352, Oct. 2, 1922).}\]

\[\text{5 Electric World, Vol. 79, p. 1166, June 10, 1922.}\]


\[\text{Radio World, July 8, 1922, p. 5.}\]

\[\text{Radio News, Vol. 4, p. 433, Sept., 1922.}\]

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Fig. 5. The final complete circuit of Lowell's five-stage amplifier, using a crystal detector and 60-cycle alternating current to supply power for the filaments and plates, as published in Scientific Papers of the Bureau of Standards, Paper No. 450, Oct. 2, 1922. The rectifier unit was in a separate box (see Fig. 1) to preclude 60-cycle hum pickup from the transformer.

amplifier. This error was due to a confusion of Circular 120, describing a simple crystal detector receiving set, with Mr. Lowell's paper describing this amplifier, which is to be published in the 'Journal of the American Institute of Electrical Engineers.' As a result of this error, both the Bureau and the Superintendent of Documents have received a great many orders for this amplifier paper. A number of storage battery companies have viewed with alarm the amplifier, using alternating-current supply, as a probable source of a marked decrease in the storage battery business. Some storage battery companies have sent representatives to the Bureau to get the details concerning this amplifier, and they have been supplied with information as to the possibilities and the limitations of the device.  

The most important patent of the three, 1,455,141 issued first, on May 15, 1923. It covered broadly the operation of any radio receiver from AC, the interfering hum being removed by specific means which were in themselves old, but had never been used in combination before. This patent, however, was not assigned to the Radio Instrument Co., because a new entrepreneur had appeared on the scene: William Dubilier.

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Fig. 6. William Dubilier hit the headlines at the age of 22 in 1910, with his wireless telephone station at Seattle, but he was a New York native, had sold wireless stock for A.F. Collins, and had originally been attracted to radio by a 1903 Marconi lecture. He became better known for mica transmitting condensers, obtaining basic patents and (under John Firth’s aegis) building up a large commercial and govern-ment business. He remained with his company (later Cornell-Dubilier) for his entire career.

Photo: Radio Guide, April, 1925.

EXPLOITING THE PATENTS: 
THE SUPER-DUCON AND OTHER B-ELIMINATORS

Dubilier was probably attracted by the commotion in mid-1922, though he claimed he had met the inventors while filing his own patent applications on AC-powered receivers, which he then withdrew. In any event Dubilier lost no time in securing an exclusive license (other than the U.S. government’s “shop right”) under Lowell and Dunmore’s pending applications, also obtaining the right to sublicense and to bring suit for infringement. Lowell, Dunmore, and Dubilier would split any royalties, according to later accounts.

But Dubilier had more than royalties in mind. He wanted to manufacture B-battery eliminators—a bold step when such things did not yet exist. Here was a tremendous potential market, as B batteries were a considerable expense to radio owners, and becoming more so as multi-tube radios proliferated. None of the large manufacturers seemed interested in developing such a product: RCA was content to feature portable models using GE’s 199 or Westinghouse’s WD11 that minimized battery consumption, and in any event had no research laboratory of its own until 1925.

So Dubilier set to work. Harry Houck, Armstrong’s assistant, who in 1923 had just finished consulting work on the Radiola Superheterodyne,7 joined the Dubilier Condenser & Radio Corp. and began development of the “Super-Ducon.” Dubilier later claimed to have sunk $500,000 into this project. Houck completed his assignment, and advertisements began appearing in May, 1924, although there is no indication that any Super-Ducons were sold until November.

7 Houck originated the “second-harmonic” principle that allowed a single tube to function as oscillator and mixer. Rather than run the oscillator only 42 kc from the signal frequency (impossible without the two tuned circuits interacting), it was run at half the frequency so that its second harmonic was 42 kc away (Radio Broadcast, July 1924, pp. 198-207).
Fig. 7.  

Source: Radio Broadcast, August 1924.

TAKING THE BATTERIES OUT OF THE RADIO SET

Harry W. Houck (left) is holding his invention which is said to do away with A and B batteries. It is a plug which fits into any alternating current light socket. William Dubilier, radio manufacturer, is pointing out to the audience of radio editors the first model of the device. Raymond Francis Yates, of the New York Herald-Tribune is standing between Mr. Houck and Mr. Dubilier. Orrin E. Dunlap, Jr., of the New York Times is on the extreme right.

The ties between Dubilier and RCA became even closer in Dec., 1924:

"Negotiations by the Westinghouse Electric and Manufacturing Company, the Radio Corporation of America, and the Dubilier Condenser & Radio Company, looking to a working agreement among these companies whereby Westinghouse and the Radio Corporation will manufacture Dubilier's "Super-Ducon" plug, were reported the last week in December.

"At present the Dubilier Company has the exclusive right under patent to this radio part, and it is proposed to permit Westinghouse and the Radio Corporation to manufacture it on a royalty basis. The Super-Ducon is expected to prove an efficient substitute for "B" batteries."

Apparently this did not mean that Westinghouse would build Super-Ducas, but rather B-eliminators for RCA under Dubilier license. These were

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8 Radio Retailer & Jobber, Jan., 1925.
9 The Uni-Rectron also included an audio power amplifier using a UX210 tube. The 213 began at GE in the fall of 1923 and was designated UV213 by RCA in December. Originally capable of 10mA at 90 to 100V output, its ratings were increased to 65mA at 170V by the summer of 1924 at RCA's request in March. However, RCA did not ask for samples until Feb. 1925—evidently the date when the Duo-Rectron was first designed. In 1927 the Westinghouse 280 superseded the 213. (Tube Development by the GE Co. of Radio Receiving Tubes, Mar. 1, 1929, Confidential).
the Uni-Rectron and Duo-Rectron, introduced in Oct., 1925, the Uni-Rectron having a half-wave rectifier UX216 and the Duo-Rectron a full-wave UX213.\(^9\)

Simultaneously the Super-Ducon was undergoing changes. Prices first appeared in its advertising in Dec., 1924: $47.50 for the AC model, $30 for the DC (DC supply was common in New York City at the time). By April, 1925, there was a “new model,” type 800. And in Oct., 1925, the Super-Ducon was “perfected with specially-designed RCA tube” and was “now furnished” with the UV196 Rectron, still at $47.50. The Duo-Rectron, incidentally, was $65, but there were several competitors offering B-eliminators for much less.

Two companies, particularly, moved aggressively into the B-eliminator field: Philco and Grigsby-Grunow-Hinds (Majestic). Majestic was an insignificant maker of horn speakers until it embraced the Raytheon gaseous rectifier and built an excellent and popularly-priced eliminator around it. In 1927 Majestic grossed nearly $5 million on essentially this one product, more than most receiver makers were taking in. Philco had become interested in radio in the early twenties, as a market for its storage batteries. It had done well selling automotive batteries for aftermarket ignition systems and for replacements,
Fig. 10. The UV196 was developed by Westinghouse in 1924, patterned on Houck's design (patent filed July 18). Unlike all other full-wave rectifiers, this one had a common plate and two independent filaments. One disadvantage of this arrangement was that it required five terminals, so the metal shell was tied to the common plate (this was grounded in use). The right-hand specimen came in the box shown, with the data sheet dated 2-18-26. The other tube, earlier, has less gettering and shows the internal construction.

1,905,872. THERMIONIC VALVE. HARRY W. HOUCK, East Orange, N. J., assignor to Dubilier Condenser Corporation, New York, N. Y., a Corporation of Delaware.Filed July 18, 1924. Serial No. 726,841. 6 Claims.
(Cl. 250—975.)

2. A thermionic valve having a common anode in the form of a hollow body with wide exterior faces, a plurality of cathodes positioned adjacent to and extending parallel with said faces, the anode being positioned intermediate said cathodes and extending in overlapping relation thereto to shield the cathodes from each other, and means supporting said cathodes extending through said hollow anode.

Fig. 11. Reproduction from Harry Houck's original patent filed in July, 1924.
but once automobiles began to be equipped with electrical systems by their manufacturers, Philco lost this O.E.M. business to others such as its Philadelphia neighbor Exide. Radio was Philco's salvation.

Philco, of course, needed no Dubilier patent license to sell A or B batteries, but it did take out a license for its eliminators, as did Majestic, since the Lowell and Dunmore patents purported to cover any radio operation from the AC lines, whether by built-in or external power supply. Later both companies decided to build complete radio sets, and soon dominated the industry: Majestic in 1929, Philco in 1930 and beyond.

By Aug., 1926, Dubilier had abandoned the Super-Ducon as "interfering with the business of its own customers" (Dubilier sold filter condensers) but the Radio Retailer & Jobber observed tartly that the company had on hand 2000 AC models and 3000 DC "which it either cannot sell or is afraid to. . . .the Super-Ducon was costly, clumsy, dangerous, unpopular. . . .the pace of improvement set by competitors speedily consigned it to the ash can. 'Tis easy to abandon what other people discard."

Dubilier's own press release a year later blamed the failure of the first Super-Ducons on the rectifier tubes supplied by RCA which "proved inoperative" and were replaced later by Raytheon.

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10 Radio Retailer & Jobber, Aug., 1926. The editor was no friend of RCA or its affiliates in the "radio trust," which Dubilier was presumed to be, at that time.
tubes.\textsuperscript{11} Evidently good will between RCA and Dubilier was fast evaporating.

The AC tube—or rather, RCA's AC tube—sounded the death knell for batteries and battery eliminators. A flock of true plug-in-the-wall radios appeared in late 1927, led by RCA's Radiola 17 and Atwater Kent's 37, as the industry scrambled to make use of the new 226 and 227 tubes. Now even the non-technical owner could have a radio, and mass entertainment over national networks flourished. All the better for Dubilier; the Lowell & Dunmore patents were just as necessary for powering 226s and 227s as they were for last season's B-eliminators.

DUBILIER TAKES ON THE INFRINGERS

Dubilier sued the Batteryless Radio Corp. (B.F. Miessner's original company, which tried in 1925 to market an AC radio) on July 14, 1926 and then, when it looked as if Batteryless would not last long enough for a final decree, sued Freshman on Oct. 14. Neither suit got anywhere, so finally on Sept. 20, 1927, Dubilier sued RCA itself. Several other manufacturers\textsuperscript{12} had by now taken out licenses from Dubilier, but not RCA, which was, however, licensing everyone else in sight under its patents and seemingly raking in huge royalties. Lowell and Dunmore's two other patents had by now issued on Nov. 9, 1926, and July 5, 1927. Patent Office interference proceedings by Latour against certain claims of patent 1,455,141 had finally been denied by the Board of Examiners-in-Chief (leaving Westinghouse, Wired Radio, and Mu-Rad who were eventually knocked out in 1931). With Lowell and Dunmore's position established more firmly than ever, Dubilier was invincible.

\textsuperscript{11} The press release was printed in \textit{Radio World}, Oct. 1, 1927, without mentioning RCA or Raytheon. \textit{Radio Retailer & Jobber} of Oct., 1927 embellished the story somewhat, as was that editor's habit. Whether one paper deleted the names, or the other added them, is open to interpretation. The subject of the press release was Dubilier's suit against RCA.

\textsuperscript{12} As of Sept., 1927: Willard, Fansteel, Philco, Argus, Timmons, Majestic, and Kolster. Western Electric/AT&T took out one in Dec., 1929, as did RCA in 1930.
Dubilier won the first round with RCA on Aug. 12, 1929, when Judge Morris of the Delaware District Court ruled that key claims of two patents had been infringed.\textsuperscript{13} Dubilier officials began talking of $10 million damages to be levied on RCA and other companies, and although RCA immediately appealed the decisions, its position did not look very promising. RCA reportedly tried to buy majority control of Dubilier two or three times, by offering more than market value for large blocks of its stock, but the owners would not sell.\textsuperscript{14}

**THE GOVERNMENT SUIT**

Then, curiously, the federal government stepped in, when the Dept. of Justice on Apr. 29, 1930, filed suit against Dubilier for title to Lowell and Dunmore’s three patents.\textsuperscript{15} It was a well-settled principle that “One employed to make an invention, who succeeds, during his term of service, in accomplishing that task, is bound to assign to his employer any patent obtained. The reason is that he has only produced that which he was employed to invent. His invention is the precise subject of the contract of employment.”\textsuperscript{16} The bill of complaint alleged that Lowell and Dunmore were employed

“To carry on investigation research and experimentation in such problems relating to radio and wireless as might be assigned to them by their superiors. . . in the course of his employment as aforesaid, there was assigned to said Lowell by his superiors in said radio section, for investigation and research, the problem of developing a radio receiving set capable of operation by alternating current. . .”\textsuperscript{17}

and therefore the United States was entitled to the patents.

However, Judge Nields of the Delaware District Court found otherwise, dismissing the suit on Apr. 27, 1931, this decree being affirmed by the Circuit Court of Appeals on May 24, 1932 and finally by the Supreme Court on Apr. 10, 1933.

“The problem of applying alternating current to broadcast receiving sets. . . was not involved in or suggested by the problems

\textsuperscript{13} Claim 9 of 1,635,117 and claims 3 and 14 of 1,455,141. Patent 1,606,212, for a power amplifier, had not been infringed. 34F(2d)450, also 391 OG 8. (Translation: Federal Reporter, Vol. 34, 2d series, p. 450; Official Gazette of the U.S. Patent Office, Vol. 391, p. 8).

\textsuperscript{14} This is from Radio Retailer & Jobber, whose editor, as noted earlier, was not noted for impartiality toward companies he disliked.

The Dubilier Condenser Corp. had been purchased in 1924 (with Freed-Eisemann and Ware) by a group of financiers led by Hugh Prichitt, a “boy wonder” in stocks who, however, lost everything in 1925, had a mental breakdown, and later died. Dubilier in 1929 was controlled by the Harriman interests and by William Dubilier once again.

\textsuperscript{15} There were three suits: against Dubilier Condenser Corp. in Delaware, the Morkrum Corp. in Maine, and Lowell and Dunmore in Brooklyn.

\textsuperscript{16} Supreme Court decision, Apr. 10, 1933, printed in the Patent Office Gazette May 2, 1933, 430 OG 4.

\textsuperscript{17} 430 OG 7
with which the radio section was then dealing and was not assigned by any superior...It was independent of their work and voluntarily assumed.”

Since under existing law the United States had no more rights than any other employer to appropriate inventions not directly resulting from assigned work, and since there had been no contract or understanding to assign other inventions to the employer, Lowell and Dunmore were free to patent their inventions and profit from them.

"The courts should not declare that a public policy forbids one employed by the United States for scientific research to obtain a patent for what he invents. A declaration of such a policy must come from Congress and no power to declare it is invested in administrative officers."

This policy would not be changed until 1940, and further in 1950, when an Executive Order announced that any invention developed by a government employee in the course of his work belonged to the government.

Just what provoked the Justice Dept. suit is not clear. Cochrane states that it was "at the prompting of the Bureau," but it is hardly likely that the Bureau of Standards had any such pull in the Justice Dept., or anywhere else. Perhaps some disgruntled radio manufacturer did have the pull. At any rate, by the end of 1931, when the government suit had met its first defeat, Dubilier occupied a commanding position.

THE FORTUNES OF WAR

Dubilier’s fortunes turned in 1932, when on Mar. 19 the Third Circuit Court of Appeals reversed the District Court rulings, finding that the patent claims in suit were invalid. The means employed for eliminating hum had been previously patented by White (1,195,672 for a center-tapped filament transformer) and Heising (1,432,022 for an artificial center-tap with bypassed resistors). While Lowell and Dunmore were the first to use them in combination, these means operated the same in combination as they had independently. Mr. Justice Woolley, speaking for the Court, said:

"Therefore, in the final analysis, the claimed invention consists in applying curbed alternating current to the detector section and the audio frequency amplifier section and also to the radio frequency amplifier section in the same way that it had previously been applied to the last named section. Is this invention?

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18 430 OG 5
19 430 OG 4
20 Cochrane, Measures For Progress, 1966, p. 349. How this Executive Order was reconciled with the 1933 Supreme Court decision is unexplained.
It might be invention if, when operating, some hum should develop in the first section and pass over to the second section, or if hum in the first two sections should invade the third section and be suppressed before it reaches the loud speaker by the three hum eliminators coacting to that end. In other words, there might be invention if the hum eliminators, though separately placed, functioned together on the circuits of all sections in eliminating wandering hum. There is, however, no suggestion of such hum action, and no such inter-relation or coaction of separately placed hum eliminating means is claimed for the invention. Instead of doing anything like this, the plaintiffs themselves claim that the hum is killed "at the source"—at the mid-point connection—that each eliminator stops the hum in the tubes of its own section, or rather, as we look at it, each eliminator prevents hum from developing in the tubes with which it alone is connected, leaving nothing for the other eliminators connected with the other sections to do with the tubes of its section or with hum in them. So it appears that each eliminator performs in the apparatus of the combination claim the same function that it performed in the device from which it was taken***; that is, each does its own work in its own section and is through. The result, in theory at least, is complete hum prevention or elimination in each section by each eliminator. It follows that the effect of the operation of all the eliminators is an aggregation of separate results***, all alike and all admittedly obtained by prior art means. From the very nature of the circuit connections, the three eliminators act independently of one another***. Operating separately yet in conjunction with the other elements of the combination, they evolve no new co-operative function,***, and the new result, as claimed, is only that which arises from the well-known operation of each one of the several elements of the combination.***\22

After its petitions for certiorari to the Supreme Court were denied, Dubilier had exhausted its legal remedies and by law could do only one thing to save its patents: file a disclaimer of the invalid claims. Dubilier did this for patents 1,635,117 and 1,455,141 but rather than jettison the invalid claims, tried to qualify them by excluding only certain features. Perhaps this was to avoid prior work of rival inventors brought out by the trial testimony. Abandoning the invalid claims would have left mainly claims specifying a crystal detector, hopelessly obsolete by the 1930s, making the resulting patents virtually useless (now, of course, crystal detectors or solid-state diodes have returned).

Immediately Dubilier filed infringement suits against different defendants in another circuit (A.G. Triplett et al., Maryland).\23 The new defendants moved

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23 Final dismissal decrees had come on June 29, 1933. The disclaimers were filed on July 8. The new suits, against A.G. Triplett et al., were filed on Aug. 17, 1933.
large capacity; at the other side of this
is the sending key, and behind the
tuner is the potentiometer. At the
left of the table is a double-throw
switch with a swing of 35 degrees,
with 2 points at the bottom and 2 at
the top, this switch takes the place of
an anchor gap. On the stool is my
loose-coupled tuner, which I have just
finished.
My transmitting instruments consist
of 3 Leyden jars, sending helix, made
d of zinc strips wound on wooden pegs.
Over this is the hot-wire meter and
capacity gaps. The jar at the right
of the table is a Wehnelt-Cadwell
terrupter as described in the December
issue of Modern Electrics. I use
in series with my coil and the A.
current.
My aerial consists of 5 wires, 3
one tree, 55 feet high, and 2 to
other, about 60 feet high, from my
tical window.
I began experimenting with wire
last winter, and have had good success
much of which is due to instruc
tions given in Modern Electrics.
Massachusetts. Francis Dunmore

Fig. 14. Dunmore's station, as
described in Modern Electrics,
tured in Radio World, May 13,
June, 1909.

Fig. 15. Francis Dunmore, as pic-
tured in Radio World, May 13,
1922.

to dismiss the suit, on grounds that Dubilier's disclaimers were tardy and in-
adequate, and the District Court concurred, but the Fourth Circuit Court of
Appeals reversed and ordered a new trial. This time the Supreme Court agreed
to review the case, because it involved differences between two Circuit Court
decisions; it affirmed the Appeals Court decision ordering a new trial. The
Justices allowed Dubilier to postpone its disclaimers, while a suit was under
way in a different circuit, because the claims might be judged valid in the se-
cond suit even though they were invalid in the first. The risk was that, if the se-
cond court also invalidated the claims, the entire patent would be void, since
under the law Dubilier would then not have filed an adequate disclaimer in
time. Sort of "double or nothing." And in fact this is what happened. Claims
9, 11, and 12 or 1,635,117 and claims 1 to 4, 7, 13, 14, and 18 of 1,455,141 were held invalid. An appeal was taken on Oct. 5, 1937, and the Circuit Court of Appeals affirmed their invalidity.

It was even worse. The suits against Triplett also involved the power-amplifier patent 1,606,212, and in the new trial, the District Court had ruled claims 1 through 9 valid and infringed. However, when the Appeals Court declared them invalid, there was no further recourse for Dubilier.

Yet two of the patents had a sort of "afterlife." Dubilier on Aug. 16, 1938, filed a disclaimer to 1,606,212; again, like the older disclaimers to the other patents, it did not eliminate the invalid claims outright, as the law required, but simply limited their coverage somewhat. Patent 1,455,141 was reissued as 21,023, Mar. 7, 1939, with more limited claims (the purpose of the reissue statute). Since neither patent was apparently litigated further, it's hard to say what the intention was. Dubilier had combined its manufacturing operations in June, 1933, with the Cornell Electric Manufacturing Co., Inc., the offspring concentrating on capacitor manufacture rather than patent litigation. The Dubilier Condenser Corp., which owned part of Cornell-Dubilier, was dissolved in 1942.

In the end, what did Lowell and Dunmore have to show for their pioneering work? They are thought to have received $30,000 apiece from RCA, in a settlement of some sort, during World War II. Dunmore used his sum to build a country house in French Provincial style. But otherwise, laurel wreaths were few and far between, and both men remained with the Bureau as regular employees until retirement.

24 17 F supp 996
25 97 F(2d) 521
26 Letters dated Jan. 16 and Feb. 29, 1988, to the author from Wilbert F. Snyder. Snyder learned of the settlements in conversation with Dunmore at the time, and can recall details of the talk, though not necessarily the exact dollar figure. It is possible that Lowell and Dunmore simply sold their patents to RCA when the Dubilier Condenser Corp. was dissolved in 1942.

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Alan Douglas

Alan has been collecting radios since grammar-school days, when he asked his grandparents for their Atwater Kent 20 and then their 1928 Philco highboy. After obtaining his BSEE from Swarthmore in 1965, his interests began to include the development of the radio-manufacturing industry, as reflected in the popular and technical journals of the day. Further data came from the men themselves, its creators, through correspondence and interviews. Combined with similar material gathered by many others, he has fashioned it into a three-volume series of books on the industry's first decade and numerous magazine articles on a variety of related topics in radio and electrical history.
Ernest C. Mignon

As he appeared in 1915, the year he established the Mignon Wireless Corporation.
THE RADIO APPARATUS OF ERNEST C. MIGNON

Lauren A. Peckham
Breesport, N.Y.

Ernest C. Mignon was certainly one of the pioneers in wireless, but little has been published about this interesting man and his radio products. His background is obscure, but it is known that he emigrated from his native Austria sometime before 1910 to Elmira N.Y., where he became employed as an installer for the New York Telephone Company.

His first experiment with "wireless" was done in 1910 at the New Lexington, a boarding house near the telephone office in Elmira. Mignon had become a friend of "Doc" Gerhart, an electrician at the Mozart Theatre, and the two men installed a wireless station at the Lexington. The antenna was located on the roof over the stage of the Mozart, the highest point in the vicinity.

A local newspaper, the Elmira Star Gazette, on October 31, 1910, gave the following account of Elmira's first wireless station: "Aerograms will be sent to distant places - not an experiment or a plaything, but a commercial undertaking." The story went on to report that the new station would be capable of communicating with the wireless service on land and sea. The cost of messages was said to be comparable with wireless rates in use throughout the world. A description of the equipment noted that a double tuning coil was on order, and copper and aluminum wires were used for construction of the aerial to "overcome any kind of weather condition." The article concluded with the statement that "Mr. Mignon is a former officer in the German army."

Unfortunately, these final words were to haunt Mignon in the future. Whether his commercial wireless service was a success is unknown. I should mention at this point that his name was pronounced MIGG-NONE, according to persons still living in Elmira who knew him.

Mignon was certainly in good company during these early times. In 1910 Elmo Pickerill and Wilbur Wright tested wireless communication between the ground and a biplane, Lee DeForest set up equipment to broadcast from the stage of the Metropolitan Opera House in New York, and Alexanderson demonstrated a 20-kHz alternator for wireless transmission.

By 1913 Mignon was building receivers for radio amateurs, actually prototypes of what eventually became the RCI time-signal receiver. One of these (Figs. 2, 3) was a tuner with three five-inch diameter coils wound together. The primary, wound of approximately 36-gauge wire, had taps brought out in groups of three and four.
Fig. 2. The RC1 prototype. Note the galena detector hand made by the owner in 1913.

Fig. 3. The interior of the RC1 prototype, showing the ring-type coil.
In the spring of 1915 the Mignon Wireless Corporation was chartered with a capital stock of $5,000, to manufacture and deal in wireless instruments and apparatus for wireless messages. Mignon’s friend, J.G. “Doc” Gearhart, was vice-president.

A 16-page catalog, No. R-5, lists six tuners, including the RLC4 receiver complete with DeForest Audion Bulb. The RC1 also made its first appearance at $10.00 (Fig. 4), showing a significant improvement when compared with the 1913 prototype.

The RLC2 Special shown in Figs. 5 and 6 contained the “Mignon Rotary Loose Coupler.” Oval-shaped primary and secondary coils were supposed to “flatten the magnetic field instead of the concentration to a sharp point with the common circular tube.” The same catalog noted that external detectors were required for the RC1, RC2, RLC2, RLC2 Special, and the RLC3 Special. Either the DeForest RJ-4 or the PN Audion Detector could be used, although the Crystaloi type AA was also suggested.

Mignon covered the bases very well in his initial year of operation, as the RLC2 Special was advertised in the September, 1915, issue of the World’s Advance magazine. Interested persons were invited to write for literature to the Mignon Wireless Corporation, specialists in radio signal receiving apparatus. He also placed an ad for the RC1 in Catalog No. 15 of the Electro Importing Co. It was listed as “The Mignon Vario Selective Coupler”, and sold for only $5.50. Of interest is the fact that this receiver was the only equipment offered that was not manufactured by E.I.

Likewise, in 1915 Mignon published a magazine, The Radiogram. The only issues printed were May, June, July, and August, 1915. Vol. 1, No. 1, notes
Fig. 5. The RLC2 Special of 1915; it sold for $30.00.

Fig. 6. Interior of the RLC2 Special. Note the elaborate loose coupler supported on a wooden cage-type form.
that the yearly subscription was $1.00, and one could participate in the "Apparatus Exchange" column for 2 cents a word. It was a stated that "The Radiogram is published in the interests of Wireless Amateurs and manufacturers of radio apparatus, giving the Amateurs an opportunity to make known their opinions and ideas to all other experimenters."

Included was an article on "Train Dispatching by Wireless" and a list of calls of stations located in Hoboken, Scranton, and Buffalo. There are also some excellent photos where a DeForest wireless telephone is plainly visible. A few short stories were included for good measure, along with a description of the Eugene Turney Crystaloi Detector. Readers were invited to obtain instructions in the duties of a Station Agent or Telegrapher by enrolling at the Railway Commercial Training School, 115 Main St., Elmira, N.Y.

The remaining three issues of The Radiogram contained many photographs of amateur stations, including one of Hiram Maxim's huge six-wire flat-top antenna at 1ZM. A detailed description of 24 stations gives a listing of the equipment of each amateur. Those of us who like early wireless material look at such items as Murdock loose couplers, Blitzen tuners, an RJ5 Audion Control Box, and the F.B. Chambers Triple Valve Receiver with envy!

Fig. 7, taken from The Radiogram, shows an amateur station of the type in existence in 1915. A Mignon RLC2 has a prominent position on the operating

Fig. 7. The radio station of M. Eiffert, 155 Oakwood Ave., Elmira Heights, N.Y., as reproduced from The Radiogram, 1915.
Fig. 8. Catalog page detailing the Mignon RLC4 Special receiver. The price was an impressive $150.00.

table, while the homemade detector allows a choice of three different crystals.

In 1916, the Mignon Catalog R-6 described a new model, to be known as the RLC4 Special. It was a fancy version of the RLC4 with a larger cabinet, more coil taps, and a rotary switch enabling the operator to use either an Audion or a Mineral Detector. The fact that the set had “genuine Platinum contact points” was also mentioned!

Other equipment advertised included the DeForest RJ8 Detector and type EJ1 Audion Amplifier. The catalog had a schedule for receiving time signals from Arlington, and a chart showing the code used to describe weather conditions was printed on the back cover.

The *Wireless Age* magazine for March 1916 contained a half-page ad for the Mignon System Cabinet type RLC2, and bold letters proclaimed, “NO TICKERS NOR ARMSTRONG CIRCUITS REQUIRED for the reception of continuous wave signals.”

The No. 16 E.I. Catalog advertised the little time-signal receiver once again, but this time it was termed the “Electro” Vario Selective Coupler instead of the “Mignon” Vario Selective Coupler. Although the price remained at $5.50, the resemblance to the original Mignon RC1 had faded. Fig. 9 shows that the name tags and knobs now came from the E.I. stock room. Mr. Gernsback apparently decided that Mignon’s ring-shaped coils were too difficult to produce; when the author examined the set illustrated, it was discovered that the coil was wound on a cardboard cylinder similar to designs in radio construction articles of the day.
As had been his custom, Mignon introduced additional models in 1917. Heading the list of products was the RW series with the “Mignon Adjustable Disc Core.” The RW3 receiver (Fig. 10) was described in a patent filed in 1916, which included his latest idea on coil construction along with a description of special components and front-panel design. Several pages refer to a circuit (Fig. 12) containing “new and useful improvements in wireless signal receiving apparatus.”

Mignon further stated in the patent, “This invention has relation to the reception of the same in the form of telegraph or telephone signals. Another object of the invention is to provide a receiving system embodying the audion type of detector and a novel arrangement of associated inductance and capacity elements, for permitting the production of “beat” oscillation whereby sustained or undamped waves may be received.”

Apparently hand capacity was a problem long before most of us experimented with one-tube regenerative sets, as the patent states, “...said arrangement acting to reduce the sensitivity of the system to variations in the frequency of the oscillations due to close proximity of objects or the operator’s body.”

Mignon also had some ideas on heterodyne principles with his theory that the coils surrounding the audion “allowed the incoming oscillations passing therethrough to be synchronized with the local oscillation to clarify the signals.” Then follows some five pages concerning the construction of the primary, secondary, and coupling coils arranged in the form of a clover leaf,
Figs. 10 (top) and 11 (bottom). Fig. 10 is a reproduction of a catalog page detailing the RW3, while Fig. 11, from a Mignon patent, shows the interior. Note the group of batteries for the plate-voltage supply.
Fig. 12. The circuit of the RW3, as shown in the Mignon patent of Feb. 3, 1920.
Figs. 13, 14. The front panel and interior of the RWX receiver of 1917. Note the "pancake"-type coils.
the operation of an audion, the construction of the nine-terminal Silent switch for wing-voltage control, etc.

It was learned from talking with persons originally associated with the Mignon Wireless Corporation that on more than one occasion officials sent by E.H. Armstrong questioned factory personnel. After studying the RW3 circuit, their concerns can be understood, but apparently Mignon felt that through the use of external coils he was not infringing on the "feed-back" patent.

There were several versions of this receiver (Figs. 13 and 15). The type RWX is a companion tuner for additional coverage when used with the RW3S. Note the two coils encircling the bulb. According to the description of these sets, the "famous Electron Audio Bulb" was manufactured specially for the Mignon System by the Electron Manufacturing Co. It is quite likely that these double-ended tubular triodes were actually made by E.T. Cunningham.

Other receivers presented in Mignon's 1917 catalog were the RW1, RW2, RW3, RBD8, RLC6, the RCS9, and the RLC7, with a hefty price tag of $175.00. Spark transmitters were also available, but built only on order. This was indeed an impressive line of equipment that must have frustrated more than one amateur, as the total cost of the RLC6/RCS9/RBD8 combination would have been over $210.00.
A complete line of Mignon equipment was available from the William B. Duck Co., and the RW3 receiver was also advertised in QST and Wireless Age. The Electrical Experimenter magazine for March, 1917, had a very detailed explanation, including several wiring diagrams.

Although the year 1917 was the time of Mignon’s greatest production, his situation took a disastrous turn on April 6, 1917, when the U.S. declared war on Germany. A few weeks later Mignon was arrested and interned at Fort Oglethorpe, Ga. A report in the Elmira newspaper stated that Mignon was an “undesirable citizen, being an alien.”

His business associates protested and sought to have him released, but no action was taken, in spite of the fact that Mignon had been granted his first citizenship papers and his attorney was in the process of obtaining the necessary final documents. The Department of Justice never announced why Mignon was arrested, but around Elmira the rumor persisted that he had been sending wireless messages to German submarines. Whatever the circumstances, Ernest C. Mignon apparently never returned to Elmira.

After WW I ended, Mignon was released and he sold his operation in Elmira to a Dr. H.A. Moore. The Universal Radio Manufacturing Corporation was formed late in 1919, and was located in the same building formerly occupied by the Mignon Wireless Corporation, at 121-127 Railroad Ave. in Elmira.

The first Universal Radio catalog was modest, with just four items listed. These included the UM3 receiver, with a range of 200 to 2,500 meters, and a long-wave tuner for 16,500 meters, the type UL5. Another item, the ET1 Bulb Detector, is shown in Fig. 17. A mounted variometer, the type S-1, would tune to 1,000 meters, and the type S-2 covered the 2,500 meter range. The ET1 used a tubular vacuum tube and could be employed with either the UM3 receiver or the UL5 tuner.

An interesting feature of the ET1 detector is the use of variable condensers in the grid circuit and as a shunt across the phones. For a total price of $40.00,
Fig. 17. The ET1 Bulb Detector, made by the Universal Radio Corp.

this set was available with a detector bulb and twelve three-cell dry batteries for use in the plate circuit.

The catalog also included a few receivers such as the RLC5 and the RW3, left over from the Mignon Wireless Corporation. The author has seen samples of these sets with either a Mignon or a Universal name plate.

The RLC5 cannot be opened without damaging a special seal. Fine wires were embedded in red sealing wax and the Universal logo stamp applied with a hot iron. A paper label states, "Any attempt to remove either the front or rear panel will destroy the seal and the receiver will not be repaired at our factory." See Figs. 18 and 19.

One of the new receivers was mentioned in an article in the Elmira newspaper on February 16, 1920. Universal had erected an antenna between a water tank and the clock tower atop their own building, and the report stated that radio messages from coastal towns and ships at sea were picked up using a UL5 receiver. Commercial stations from France and Wales were also heard. Universal continued in business until 1922, when the Federal Radio Laboratories, Inc., was established in Elmira by the same men who had originally worked with Mignon.

Meanwhile, E.C. Mignon was back in business, this time in Newark, N.J. The new name was the Mignon Manufacturing Corporation. An announcement appeared in QST for April, 1920, stating, "The improved RW4, UW1 (Figs. 20, 21), and the BD1 are now being manufactured under Mignon patents."

Arthur B. Church, a "wireless specialist" located in Lamoni, Iowa, was one of Mignon’s retail-sales outlets. His catalog noted that the RW1, RW2, RW3, and RBD8 receivers were no longer manufactured. Obviously Mignon was not
Figs. 18, 19. The Universal Radio Corp. type RLC5 tuner, which was also manufactured by Mignon. The interior view shows the well-constructed loose coupler.
pleased that back in Elmira, at Universal, these very same receivers were still being offered for sale. They appeared on the back pages of the Universal catalog under the heading, "not quite equal to the Universal type sets." The RW4 used three coils in the form of discs, resembling over-sized choke coils. The cost, including a Marconi V.T. triode, was $95.00. The UW1, at $35.00, allowed the amateur to purchase the tuner portion if a detector was already on hand. However, the idea of separate components was common in the early 1920s, and a detector panel was also available as type BD1.

Later, in 1920 the name of the New Jersey company was changed to Mignon Manufacturing Export Corporation. Mignon was one of a group of radio manufacturers, along with A.H. Grebe and Clapp-Eastham, who obtained a license from Armstrong before Westinghouse gained control of the valuable regenerative circuit. The famous patent No. 1,113,149 was printed on the front cover of Catalog R8.

Mignon changed the model numbers from RW4, UW1, and BD1 to RW5, UW2, and BD2 respectively. Other than a price increase, there were not other differences, as the panel layouts and circuits sold by the former Mignon Manufacturing Corporation were identical.

One new receiver, the RC2, was advertised in the September, 1920 issue of QST. It was described as the "Mignon Undamped and Regenerative Radio Apparatus." A one-stage audio amplifier, type MA2, was intended for use with the BD2 bulb detector or the RW5 receiver. The correct tube was again a Marconi V.T.

In 1921 or 1922 the company moved once again, this time to Buffalo, N.Y. The Mignon System Manufacturing Company offered the RG2 (Fig. 22), an
updated version of the RC2, and a new tuner, the type UD3. The latter was
designed for reception of transatlantic and transcontinental signals, and
featured plug-in "UD" type coils, available for wavelengths from 130 to
25,000 meters.

There was an ad for the RG2 Mignon receiver in the Marshall-Gerken Com-
pany catalog. It noted that the set was equipped with full Audion control, with
adapters for both types of detector bulbs. There was a Marconi V.T. socket
behind the filament-viewing hole, but binding posts were also available for
connecting a double-ended tubular audion on the front panel. This curious ar-
rangement was carried over from the RW4/RW5 series.

As far as can be determined, the last efforts of E.C. Mignon in the radio
manufacturing field appeared in Rochester, N.Y., where, in 1923, and
possibly later, the Mignon Electric Manufacturing Corporation offered a
small line of components, including variable condensers and audio
transformers. The variables were well made; some were enclosed in celluloid,
with the plates colored red or green (Fig. 23).
**TABLE 1**

**LISTING OF EQUIPMENT DESIGNED BY E. C. MIGNON**

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1915</td>
<td>(MIGNON WIRELESS CORP.)</td>
<td>RC1 RLC2 Special</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RC2 RLC4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RLC2</td>
</tr>
<tr>
<td>1916</td>
<td>(MIGNON WIRELESS CORP.)</td>
<td>RLC4 Special</td>
</tr>
<tr>
<td>1917</td>
<td>(MIGNON WIRELESS CORP.)</td>
<td>RLC5 RW1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RLC6 RW2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RLC7 RW3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RBD8 RW3S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RSC9 RWX</td>
</tr>
<tr>
<td>1919</td>
<td>(UNIVERSAL RADIO CORP.)</td>
<td>UM3 ET1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UL5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-1 mounted variometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-2 mounted variometer</td>
</tr>
<tr>
<td>1920</td>
<td>(MIGNON MANUFACTURING CORP.)</td>
<td>RW4 RC1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UW1 DT1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BD1</td>
</tr>
<tr>
<td>1920</td>
<td>(MIGNON MANUFACTURING EXPORT CORP.)</td>
<td>RW5 BD2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UW2</td>
</tr>
<tr>
<td>1921-22</td>
<td>(MIGNON SYSTEM MFG. CO.)</td>
<td>RG1 DA2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RG2 MA2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>UD3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BT3 c.w. radio-telegraph transmitter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RP2 radio-telephone transmitter</td>
</tr>
</tbody>
</table>
Fig. 23. Products of the Mignon Electric Manufacturing Corp., Rochester, N.Y., about 1923.

Other than reports that diathermy machines were supplied for a few years, and that various types of high-voltage products were made by Mignon, the author has been unable to find any other record of Mignon's activities. So why is it that interest in the Mignon company has remained so high among radio historians for so many years? In the late 1950s, when the Antique Wireless Association was in its infancy, there was already something magical about his products. Wireless historians who still recall the great days of amateur radio in the years just prior to WW 1 have provided a few clues.

It must be remembered that in those days few experimenters could afford to purchase factor-made equipment. Fortunately, nearly everything needed for a station could be found at the local hardware store. A headset, or more likely, a single "watch-case" receiver, came from a catalog, unless one lived near a large city. As a wireless enthusiast thumbed through the pages of fascinating illustrations, he could not help pausing to dream a bit, as names which included Clapp-Eastham, Adams-Morgan, DeForest, E.I., Arnold, Chambers, etc., appeared. Along with claims of superior performance, a few testimonials from customers were often included.

And what of the Mignon Wireless Company? Sure enough, on page 120 of the September, 1915 issue of the World's Advance magazine, there is an ad for the Mignon-System RLC2 receiver. Although the DeForest RJ-4 Audion Detector, the Adams-Morgan Receiving Transformer, and a Clapp-Eastham Radio Receiving set are shown on the same page, the cut showing the Mignon tuner stands out. The reason is obvious when one takes a moment to study the panel layout. Everything from the groups of tap switch points to the large brass binding posts has an inviting appearance, with a symmetry that is reminiscent of the Navy equipment made in the same time period. Even the products of the famous Electro-Importing Company are rather plain by comparison.

Although there was nothing too unusual about the circuits, Mignon more
than made up for this by designing very intricate coil systems. As an example, a small tuner that was custom made in 1913 for an amateur living in the hills of north-central Pennsylvania has nearly 100 taps.

Later, Mignon designed a complex vario-coupler with a multi-tapped rotor that picked up some 22 turns. A delicate system of phosphor-bronze brushes allowed rotation of the primary coil, with the 22 coil taps wired to switches on the front panel. Mignon kept the dozens of leads that terminated on the inside of the panel in place by providing a wooden ring drilled at 1/2" intervals, resulting in a very neat looking cable spreader. Waxed lacing cord and brass clamps held additional wiring in place.

The Mignon Corporation manufactured nearly all of the required hardware, including the plates for the variable condensers. A gentlemen still living in Elmira remembers working in a loft area where hundreds of screws and binding posts were turned out on machines operated by boys working for a few pennies an hour.

Mignon’s private life is something of a mystery. Although he had been trained as a telephone technician in the early 1900s, how he obtained his knowledge of wireless is not known. He most certainly became an extraordinary design engineer, as the dozens of coil innovations were his own. He was not married, and apparently had no relatives in the United States. His acquaintances in Elmira treated him as an electrical wizard, but he was not close to any of them. There were times when his employees were not allowed to enter certain areas of the factory; no explanation was ever given.

Mignon’s apparatus was very attractive, and the professional no-nonsense appearance of the front panels, even when compared with commercial equipment manufactured by large companies, is a major reason for their popularity with today’s radio historians and collectors.

Photos: Jack Greible Studios, Horseheads, N.Y.

Lauren A. Peckham
Lauren has been interested in early radio equipment since the early days of WW II, when he learned how to restore them to operating condition. This developed into a strong interest in radio history, and during an 18-year employment with the Westinghouse Co. he became acquainted with H.F. Dart, their patent engineer, who knew a great deal about early radio and had worked on the development of the WD11 vacuum tube. Lauren expanded his interest in vacuum tube history and has written extensively in the QST and has given lectures on the history and identification of unusual tubes. His interest in Mignon’s receivers developed into a study of Mignon’s early days in Elmira, N.Y. He owns and operates a business engaged in the restoration of pipe organs and automatic musical instruments. An A.W.A. member since 1968, he is currently serving as President.
FOREIGN AND MILITARY TELEGRAPH KEYS

Louise R. Moreau, W3WRE        Murray D. Willer, VE3FRX
Glenolden, Pa                 Toronto, Ontario

This paper deals in the main with foreign keys, i.e. non-American telegraph and wireless keys, and with military keys of all countries. However, it is important to compare the development of the key in foreign countries with its development in the United States, and such comparisons are included where they are considered of historical interest.

HISTORICAL

From the beginning of history, up to the 18th century, the speed of communications was virtually limited to that of the horse on land and the sailing ship on sea. There were, however, some simple signaling systems used in the early days. The Greeks, the Phoenicians and the Persians used fire beacons with a prearranged code, usually in time of war. In some parts of Africa the natives used drums to pass messages from village to village. The North American Indians used smoke signals. And the British navy used flags and pennants to signal between ships. While these “telegraph” systems were useful, they all had severe limitations.

The word “telegraph”, coined in 1792 by a Frenchman, Claude Chappe, to describe his semaphore system, comes from the Greek “tele”, meaning “far”, and “graphein”, meaning “to write”. Chappe mounted his manually-operated semaphore arms on towers spaced 5 to 10 kilometers apart and equipped his operators with telescopes. He built these towers across France and into Bavaria; they were used with some success during the Napoleonic wars and up until the time the line (wire) telegraph came into being.

During the 17th and 18th century a number of scientists contributed to the knowledge of electricity and magnetism. But it was an Italian scientist, Alessandra Volta, who initiated the field of electrotechnology in 1800 when he developed the first constant current battery, consisting of zinc and copper plates in an acid solution, and later called the Voltaic cell. Other scientists soon found that electric currents generated magnetic fields, and one of the first important developments arising from this early knowledge of electricity and magnetism was the electro-magnetic telegraph.

While a number of scientists contemplated the idea of communicating by electricity, the first practical telegraph was developed by two Englishmen, William Cooke and Charles Wheatstone, who patented their needle telegraph in 1837. The needle telegraph was based on the principle that a magnetized needle, when placed near a wire carrying current, would deflect to the right or to the left, depending on which way the current was flowing. Cooke and Wheatstone mounted five magnetized needles on a large panel, and by means
of an electric current caused two of the needles to point to various letters mounted on the same panel, thus spelling out words.

However, it was an American, Samuel Finley Breese Morse, who deserves the credit for the telegraph. Morse worked on his ideas for a number of years, dating from about 1832, but he couldn’t get adequate financing. He also was not very good at building the necessary instruments, and in 1837 he formed a partnership with Alfred Vail, whose father owned the Speedwell Ironworks in Morristown, New Jersey. Vail built the instruments, and it was Vail and Morse who developed the binary system of dots and dashes to represent the alphabet, and which later was called the Morse code. Morse finally convinced the U.S. government to put up the necessary funds to build a telegraph line between Washington and Baltimore to prove the feasibility of the system. That occurred in 1844, and within a relatively few years telegraph lines were connecting most of the major towns in the U.S.

In European countries, the development of the telegraph differed substantially from its development in the United States. In France, for example, the government was unwilling to abandon the Chappe semaphore system, since it was an important government department and employed a large number of people. A commission appointed to review the matter finally decreed that, if line telegraphy was to be installed, the telegraph indicators should have two needles, each needle having eight positions, thus simulating the Chappe semaphore system so that the Chappe operators would not require complete retraining. Within a few years, however, the government, realizing the disadvantages and greater complexity of the Chappe-type indicators, and also desirous of having a system compatible with other European countries who
were using Morse type equipment, changed over to the simpler and faster Morse system.

In England, also, the system developed in a different manner than in the United States and Canada. A letter could be mailed for a penny and was guaranteed to get there the next day. This was much cheaper than a telegram and had less chance of error. Also, this was at a time when the railways were rapidly expanding their routes. So, in England, the development of the telegraph coincided with the growth of the railways, and the needle telegraph was used to control railway operations. In the U.S., with a widely dispersed population, the telegraph was used mainly at first for railroad train orders and to get news to the newspaper offices. A press association was formed in New York, and the news from Europe and New York was wired to the inland cities. Also, Samuel Morse fought tenaciously and successfully to protect his patent rights. Thus the Morse key and sounder became the preferred and accepted practice in the United States, while in England the needle telegraph continued in use for many years.

THE NEEDLE AND DIAL TELEGRAPHS

The five-needle telegraph, built by Cooke and Wheatstone, (Fig. 1) was the first British telegraph system. It was sold to the railways where it was installed with six wires. At first Cooke and Wheatstone were not too knowledgeable on how to properly insulate their wires, and after several of the wires had failed, the operators worked out a code using only two of the needles. As a result, Cooke and Wheatstone decided to develop a two-needle telegraph.

In the two-needle version (Fig. 2), each letter was represented by so many deflections of the left or right needles. Again, if one of the wires failed, the operators found they could communicate with one needle. So Cooke and Wheatstone then decided to bring out the single-needle telegraph.

The single-needle instrument (Fig. 3), with one wire and a ground return, was easy to maintain and easy to use. Each letter was represented by so many deflections to the right and so many to the left, similar to the military signal-flag system. Initially, the codes were arbitrary, but later the Morse code was adopted in which dots were to the left and dashes to the right, so that the letter B, dah-dit-dit-dit, for example, would be one deflection to the right and three deflections to the left.

In the 1850s and 1860s a number of the European countries, including England, France, Belgium, and Germany, developed dial-type telegraphs or alphabetical telegraphs, as they were sometimes called. A dial telegraph built by the Siemens firm in Germany is shown in Fig. 4. Each instrument had an indicator dial and a control dial, with the letters and numerals marked around the circumference of each dial. In this system, after the alarm was actuated, each operator placed his control dial in the 12 o’clock position. Then, as the sending operator moved his control dial past each letter, the instrument would generate voltage pulses which caused the indicator dials to move to the corresponding letter; that is, the indicator dials tracked the control dial. The dial-type telegraphs were used fairly extensively at first, but because they were slow, 10 w.p.m. or less, and because they needed two operators, one to read
Figs. 2, 3. The two-needle and single-needle telegraphs, as devised by Cooke and Wheatstone.
and one to copy, by the mid-1850s the majority of the European lines had adopted the more economical and simpler Morse system.

**THE MORSE AND CONTINENTAL CODES**

Since the Morse code lacked letters with diacritical marks, such as the German umlaut and French grave accent, it was not wholly satisfactory for use on the European continent. By agreement, a variant called Continental or International Morse was adopted by European countries in 1851, in which Morse's spaced letters such as C, O, R etc. were replaced with unspaced letters. In the United States, where the Morse code was well established, the telegraph companies considered that the move to the Continental code would cause too much confusion and they remained with the Morse code. Later, submarine cable and wireless telegraphy would adopt the Continental code.

**THE U.S. CIVIL WAR**

Military telegraph communications, established and used during the U.S. Civil War by both the Union and Confederate Armies, employed the straight lever and camelback keys from railroad and commercial telegraph services of that period. Most military signaling, especially during the first two years, was accomplished using signal flags from high locations. The Signal Corps of the U.S. Army was established, with Major Albert J. Myer as Chief Signal Officer. He recognized the potential and importance of the electric telegraph but trained telegraphers were in extremely short supply. He therefore introduced the Beardslee dial-type telegraph (Fig. 5), which did not require a trained operator. Unfortunately, this machine proved too slow when compared to the performance of skilled Morse telegraph operators, and less than two years later most of the Beardslee units were destroyed.
The Military Telegraph Service, a civilian branch of the Quartermaster Corps, was equipped with “Battery Wagons” which served in the field as telegraph offices, together with a fleet of construction wagons carrying the necessary wire, insulators, tools, etc. As the war progressed these signal facilities became increasingly important. (Grant’s message announcing Lee’s surrender was sent by military telegraph to Washington.) The principal telegraph equipment used in the mobile offices was the KOB (Key on Base) set, consisting of a sounder and a key mounted together, as shown in Fig. 6.
Figs. 6-13. 6: The KOB, a complete sending and receiving station for Civil War military telegraphers; 7: Model 1, an early Prussian key; 8: A Model 2 Prussian key, 1853; 9: The Preece plunger key; 10: Standard British Post Office key; 11: Early German telegraph key by Siemens & Halske; 12: An early Italian key; 13: Swedish telegraph key by Ericsson.

Photos: 6, L.R. Moreau; 9-13, M. Willer.
THE EARLY EUROPEAN KEYS

The "camelback" key, so named because of its curved lever, was widely used in the U.S. and was manufactured by a number of instrument makers. While it never achieved wide popularity in Europe, the Prussians liked it, and Fig. 7 illustrates one built in 1849. This was called the Model 1 and its camelback lineage is apparent.

Fig. 8 shows another camelback-type key built in Prussia a few years later, called the Model 2. However, the curve on the lever of the Model 2 was no longer important, and the design was moving toward the straight lever.

William Preece was the chief engineer of the British Post Office for many years and a very good engineer. He developed the Preece Plunger Key (Fig. 9) which was used in railway block operations. The railways developed the block system in which each railway line was divided into sections or blocks, and the telegraph was used to ensure that only one train was on one block at any one time.

Before the British Post Office took over the telegraph companies in 1870, there was a wide variety of equipment in use. While the needle telegraph was predominant, there was a mixture of other types including some dial telegraphs, some acoustical, some printing types and some Morse equipment. The Post Office, realizing the need to train large numbers of operators to take on the expanded systems, and also the need to standardize on equipment, made the decision to move to the Morse system, and the key shown in Fig. 10 is representative of the standard post office design.

In this version the spring is mounted to the rear of the fulcrum and is in tension, as opposed to the American key design, where the spring is in front of the fulcrum and is in compression. Also, the British and other European keys have an extra contact at the rear of the lever. This contact was connected to the next station through its relay. In the European system, the battery was not in the circuit until the operator started sending, i.e., the battery was open-circuit. This was termed the Open-Circuit system.

In the United States, however, the battery was always connected in the circuit, i.e., the battery was closed-circuit, so the American system was called the Closed-Circuit system. When the operator finished sending, he kept the circuit closed by means of his circuit closer, or shorting switch. Each system had its advantages, so the Europeans continued with their Open-Circuit system, while the Americans retained their Closed-Circuit system. That is why European keys have that extra contact at the rear, and American keys do not.

An early German telegraph key, made by Siemens & Halske, is shown in Fig. 11. The heavy lever and large knob are typically European. An interesting feature of this particular key is the use of two springs, one in front of and one behind the fulcrum, which allowed the operator to set the lever for very light balance. In the Siemens key the front and rear bottom contacts are mounted on springs cantilevered out from the side, giving the key a nice soft positive feel, a feature which the Germans carried right into some of their World War II designs. On these early models the contact on the lever was called the hammer, and the front bottom contact the anvil.
An early Italian key is shown in Fig. 12. There is an extra lever to the rear of the finger-piece which is thrown out of the way with the index finger when operating; then, when the operator is finished, the extra lever makes contact with the anvil, thus acting as a circuit closer or shorting switch. Hence the key could be used for open-circuit or closed-circuit work, with the extra lever removed for open-circuit operation.

Sweden's first telegraph line was built in the 1850s by a Mr. A.H. Oller, using equipment from France and Germany. Oller then set up a plant in Sweden to build telegraph equipment. One of his trainees was a bright young fellow, Lars Magnus Ericsson, who was later sent to France and Germany on a scholarship to study the techniques used in the manufacture of telegraph equipment. Ericsson returned to Sweden and set up his own company, and Fig. 13 illustrates one of his keys. However, the Ericsson key was originally designed by Oller and then copied by Ericsson. The key is unique in that the hammer is a platinum-coated laminated-steel spring fastened to the lever with two screws, with the contacts located above and below the hammer. The upper contact is called the anvil and the lower contact the boss, and the dots and dashes are made when the hammer hits the anvil. The Ericsson or Oller style of key was also copied by the Great Northern Telegraph Company in Denmark and the Ihili Company in Norway, and early keys made by these companies reveal their Ericsson design origin.
Fig. 14 is a British key, which, with its six terminals and send-receive switch, was obviously used for duplex telegraphy. The key is beautifully made and mounted on a highly-polished piece of rosewood. In duplex telegraphy messages can be sent in both directions at the same time on the one wire.

A key made by the Walters company in England in the early 1900s is shown in Fig. 15. The front pedestal contains the upper and lower contacts. The lever is fastened to the rear pedestal by means of a flat spring, and the fulcrum, which is immediately in front of the rear pedestal, can be moved backward or forward to adjust the tension of the lever; this is one of the very few keys with an adjustable fulcrum.

The double-current key (Fig. 16) was used mostly in England and in India over long lines. An ordinary single-current key sends out square, positive pulses representing dots and dashes, but in a long telegraph line, due to the capacitance and impedance in the circuit, the square pulses tend to get distorted and pushed out of shape. In the double-current key the key sends out a weak negative current in the spaces between the dots and dashes, and this negative current tends to straighten and square up the positive pulses.

WIRELESS — 1900 TO WORLD WAR II

When wireless came along at the beginning of the twentieth century, all of the transmitters were spark transmitters. Because of the heavy current required, the telegraph keys with their small contacts were not suitable, and larger keys with heavier contacts were developed.

One of Marconi’s first keys, known as the “grasshopper key”, was a rather ponderous device and is shown in Fig. 17. The key was designed to handle high current during transmissions and at the same time short-circuit the coherer or detector to prevent its destruction.

The U.S. Navy was no longer limited to flag or light signals and adopted radio, using new styles of keys capable of controlling the high power required for spark transmitters. Some keys had contacts measuring an inch in diameter, and were equipped with cooling fins to dissipate the heat generated at the contacts. High-power coastal stations frequently used a heavy-duty keying relay (Fig. 18) between the key and the primary of the transmitter. Telegraphy was also the principal method of communication for armies using either wire or radio. During World War I the U.S. Signal Corps was equipped with a new and compact “Buzzerphone”. The earliest of these were made by Stromberg-Carlson in 1914 (Fig. 19). Later units, by Western Electric, had a straight-lever key hinged in the center so that it could be locked for operation, or loosened and turned in at an angle when secured inside the case (Fig. 20).

The U.S. Air Corps used the flame-proof J-5 key which could be strapped to the thigh so that the airman could transmit reconnaissance information in flight (Fig. 21). Both the Air Corps and the Navy used the type J-7 key, equipped with a light, for monitoring a remote light-signaling device (Fig. 22).

A very early spark key built in France is shown in Fig. 23. Its maker is unknown. In this key, the contacts were immersed in oil to suppress the spark and to provide better cooling. These were called oil keys; the French were

Photos: 18, 19, 21, 22, L.R. Moreau; 21, Henry Ford Museum; 23, 24, 25, M. Willer.
Figs. 26, 27. 26: Canadian Marconi key, 1920s-30s; 27: Marconi key used at Drummondville, Quebec.

*Photos: M. Willer*

apparently fond of this design, and a number of oil keys were built by them.

Fig. 24 illustrates a Marconi key used during WWI. There were a number of different methods of keying the transmitter and disconnecting the receiver, and there is an extra set of contacts at the rear of the lever, used to operate relays to do this.

The key shown in Fig. 25 was originally installed on a Great Lakes vessel built in 1911. On first examination its heavy construction with large internal contacts and two large cable connections would indicate it was built for spark use. However, this type of key was mounted on the bridge of the ship, and when the officer on the bridge wanted to communicate with some of the ships around him without using the wireless, he would use this key, which operated the lights on the yard arm of the ship. Hence its name, “yard-arm blinker”. During WWII, some ships were equipped with an extra yard-arm blinker dubbed “Nancy”. “Nancy” operated a set of infra-red lights on the yard arm and was used if there were enemy submarines around. Special optical equipment was needed to read “Nancy”.

A Canadian Marconi key used on a Great Lakes vessel during the early 1920s and 30s is shown in Fig. 26. While the use of spark was discontinued in the 1920s, many of the ships on the Great Lakes retained their Marconi spark transmitters as back-up emergency equipment until 1940.

The key illustrated in Fig. 27 was used by a Canadian operator to control a Marconi transatlantic station in Drummondville, Quebec, from 1926 to 1963. The contact configuration in this key bears a strong resemblance to the Swedish Ericsson key, and it is possible that Marconi used Ericsson keys as replacements in some of their stations.

The Marconi Model 365, Fig. 28, was the universal key used on both land-based and sea stations before, during, and after WWII. In this model the large lever is supported on ball bearings. The British wireless operators were really brass pounders, and the heavy construction of the Marconi 365 reflects this fact.

American wireless operators usually mounted their keys at the rear of the desk and preferred operating with their arm on the desk. But the usual British
Fig. 28. The widely-used Marconi Model 365.  

*Photo: M. Willer*

custom, which they felt provided greater operating freedom, was to mount the wireless key at the edge of the desk and pound away with the wrist and arm in mid-air...and perhaps that's another reason their keys had to be heavier.

**THE SEMI-AUTOMATIC KEY — 1900 TO 1950**

Around the turn of the century a number of telegraph operators were trying to develop keys to speed up their sending. They were not too successful. Then, in 1904, an American by the name of Horace Martin received a patent for his "telegraphic transmitter", which just about locked up the design of the semi-automatic key or "bug". He called his key the Vibroplex. Martin and the Vibroplex company produced many different models of semi-automatic keys, and collecting one of each of the Martin and Vibroplex models would be a project in itself. However, by the early 1920s the Vibroplex patents were starting to run out, and a number of other companies entered the field and started to manufacture semi-automatic keys.

It was the policy of most U.S. telegraph companies to let the operator select the key he preferred, in the interest of speed and efficiency. Thus in the U.S. there was a large variety of keys and bugs developed and used. In other countries, where the government ran the telegraph systems, there was a tendency to remain with the standard straight-lever hand key; hence other countries simply did not develop the range of semi-automatics that were developed in the United States.

The Australians did produce several unusual semi-automatics, which in Australia were called "jiggers". One, built in Melbourne, Australia in the early 1930s (Fig. 29), is a sturdy right-angle jigger called the Simplex-Auto, in
which the pendulum is at right angles to the finger knob. These were made for both right and left-hand operation.

Fig. 30 illustrates a double-lever jigger made in Adelaide, South Australia, called the MacDonald Pendograph. The left lever releases the pendulum to make automatic dots, while the right lever makes dashes manually. Because the pendulum is vertical this key could also be classed as a vertical jigger. The Post Master General in Australia allowed operators to use semi-automatic keys, and a number of these which were originally supplied to the post office carried the initials PMG (Post Master General).

An unusual key manufactured in South Australia by the Hitchcox Brothers (Fig. 31), is a triple-lever key called the Automorse. It has one lever for automatic dots, one lever for automatic dashes, and one lever for manual dashes. Its many adjustments makes it a difficult key to set up properly. While it is a most interesting design, it does appear to be a bit over-engineered.

So far as can be determined, there was only one bug produced in England on a production basis. This was known as the Eddystone beetle bug (Fig. 32). The British should be given special credit for this design, as it is the only “bug” that looks like a bug.

A semi-automatic key made by the Swedish Radio Company (Fig. 33) carries the designation “Bug 140”. C.W. operators who are familiar with the famous American McElroy key will spot some of the rugged design features
borrowed from the McElroy key. The heavy tee bar can be used for carrying, and also permits the key to be turned on its side; with the pendulum locked, it can be used as a straight hand key.

A key built by Rolph Brown of Toronto, Canada (Fig. 34) was called the Xograph. Rolph was an operator with the Canadian Pacific Telegraph Company and built bugs in his home basement back in the early 1920s. They were quite small, somewhat like the Vibroplex Blue Racer, and it is possible that Vibroplex borrowed one or two ideas from Rolph.

Fred Wilcox was an operator with the Canadian National Telegraph Company on Toronto. Fred was a pretty good machinist and had a machine shop at home where he manufactured bugs which he sold to his many friends who were telegraph operators. Fred didn’t want his keys to move around the operating desk, so all his keys (Fig. 35) had heavy bases. They were made during the early 1920s, with serial numbers up to about 1500.

Paul Dow, of Winnipeg, Manitoba, built a number of bugs. Paul believed that, for ease of operation, the pendulum should be inclined at about 30 degrees, and in one of the bugs he built (Fig. 36), he actually inclined the pendulum and the bridge together with the dot and dash contacts at 30 degrees to the vertical. This was dubbed “The Bent Bug”. In most bugs the base was of steel, with the upper brackets and lever of brass, but Paul made this model all of bronze.
In the 1950s Paul Dow went a little further and made the pendulum adjustable, so that the operator could set it at any angle for greater operating ease (Fig. 37). The set-screw at the top locks the rotating mechanism once it has been set at a convenient angle. The Canadian Dow Company was later taken over by an American Company, so the same key may be found with the label marked "Warren, Minnesota", instead of "Winnipeg, Canada".

A semi-automatic key adopted in the thirties by the U.S. Signal Corps was designated the J-36 (Fig. 38). It was manufactured originally by the Brooklyn Metal Stamping Company. Another noteworthy semi-automatic speed key made by Martin for the military during WWII was the "Rotoplex" (Fig. 39). This key was built with a quite substantial ball-bearing lever support.

**WORLD WAR II — THE MILITARY HAND KEYS**

When WWII came along there was a tremendous increase in communication requirements, and several keys which were developed during the 1930s immediately found use. Fig. 40 shows a key used before, during, and after WWII in Royal Air Force ground stations. It carries the designation "Key. Morse. type D Ref. No. 10F/7373 Air Ministry", and its heavy lever, large silver contacts, and large cable clamps indicates the builders may have designed it initially for spark use.
Figs. 41-44. 41: WW II keys, British Army and RAF; 42: RAF WW II "bathtub" key; 43: RAF light-signaling key, WW II; 44: 1941 J-37 U.S. military key...steel lever and leaf spring on a dielectric frame; could also be designated J-41A, J-43, J-44, J-45, J-46, J-47.

Photos: 41, 42, 43, M. Willer; 44, L.R. Moreau

A number of keys were built during the war for the British army and the RAF by various manufacturers, all to the same general specification, but differing in detail (Fig. 41). The one on the left, with the protective disc, was made by Western Electric for the British Air Ministry, and the body carries the Air Ministry markings with crown. The next one was made by Bunnell, with all the upper hardware of polished brass. The third one was by the Canadian Westclox Company, with the brackets all of pressed steel. The last one was by a British company, with the body made of plastic, except for the brass contacts and terminals. These keys all had the same standard base so they could be interchanged. The Westclox keys were also made with a steel enclosure fitted with web straps which fastened to the operator’s thigh, for use in vehicles or tanks. All of these keys had an extra contact for possible use in land-line, open-circuit telegraphy, or for receiver-relay operation. The keys carried the designation “KEY W.T. 8 AMP NO. 2”.

A key used on British bombers (Fig. 42) was dubbed “the bathtub key” because of its shape. The design was unusual in that all of the hardware was fastened to the top portion of the plastic enclosure. If the aircraft was going to ditch in the sea, the operator pushed the spring clip over the protective skirt of the knob to send out a carrier signal to assist in locating the downed aircraft.

Photos: 45, 46, 47, L.R. Moreau; 48, M. Willer

The flame-proof key shown in Fig. 43 was used in a number of British aircraft, mounted at the side of the pilot’s or navigator’s position. The switch on the face of the key, marked “Upward Morse” and “Downward Morse”, operated the lights on the top and bottom of the aircraft to signal aircraft in formation without using wireless. This was a type of “yard-arm blinker” for aircraft.

The U.S. Military, prior to and during World War II, used keys bearing type numbers J-37, J-38, and several others following J-41 (Figs. 44, 45). These were used in large numbers, and many manufacturers were involved in their production, including Bunnell, Western Electric, Lionel and E.F. Johnson. It is interesting to note that the J-38 was also produced in France by Vuillemot Creteil with the designation “J-38FR” stamped on the underside of the frame. One model of the J-37 (Fig. 46) was arranged with a leg clamp for mobile use. It was used in trucks, jeeps and armored vehicles, but not in tanks; it was not safe in the enclosed environment, as it was not designed to be flame-proof.

Another key developed for use in U.S. Navy aircraft was the special SE-1443A flameproof key (Fig. 47). It was later used during the Byrd Expedition in 1934.

A key used by the Swedish Navy before and during WWII, (Fig. 48) reflects
the design of the original Ericsson telegraph key. It has one lever with two hammers, but is operated like a conventional single-current key. The first hammer was connected to the oscillator circuit and made contact a few milliseconds before the second hammer, which was connected to the amplifier circuit. This gave the oscillator circuit time to stabilize before the amplifier was connected.

Another Swedish key is shown in Fig. 49. This was made for the Swedish army by a number of different contractors, and its contact configuration shows the Ericsson design influence. However, in this model the lever is suspended on a thin, very flexible steel spring, which gives the key a soft, positive feel; a beautifully-made key and a nice one to operate.

There were very few keys made in South Africa. The KMK-2 key (Fig. 50) was made for the military by the S.M.D. company in Pretoria. The finger knob is in a well-protected location. There are two large connectors on the key, one on each side, with six sets of wires running through the key. However, only one set was connected to the key contacts. The five extra sets of wires were run through the key apparently to simplify the transmitter cabling.

A key known as the Baumuster T-1 (Fig. 51) was used extensively by the German forces. It is mounted on an aluminum sub-base which has a rubber
overshoe with large pimples on its bottom to prevent it from slipping on any surface. The finger knob is concave, which many operators considered an improvement over the flat-type knob. In this version the bottom contacts are mounted on springs cantilevered out from the side, a feature borrowed from the early Siemens telegraph key, providing a soft, quiet operation.

Fig. 52 shows a sealed, flame-proof type key built in Canada for the British Admiralty. It appears to have been designed for use with submarine detection equipment, although confirmation of its exact use is still lacking.

**TODAY**

Most of the companies that manufactured keys during the last 140-odd years have now faded into history. However, there are still a few firms building keys, mostly for amateur radio operators. The one shown in Fig. 53 is made in Japan, is still available, and combines a straight key with an automatic key on a common base. Called the Hi-Mound Compound key, it is certainly intriguing. The Japanese decided that if they were going to build a good automatic key they would incorporate every possible adjustment. This key has it; it is a bit over-engineered, but a unique key for the C.W. operator who has everything.

Alfred Vail’s 1844 “Lever Correspondent” style was eventually adopted by all countries for telegraph and radio use. In English-speaking countries it is termed a “Key”. In Germany we find “Der Morse Taste”; in France “Le Manipulateur” (frequently shortened to “Le Manip”). In Japan it is the “Den Ken”, and in Israel the “Maft’ay’ach Telegraph’he”. But whether the instrument is a bug or a hand key, everywhere it incorporates the original idea of “a lever acting upon a fulcrum;” the key, once referred to by Ed Raser, the dean of key collectors and historians, as “the fundamental symbol of the art itself.”
Figs. 54-57. Miscellaneous keys not referred to in the text: 54: 1900 Double-lever Bunnell Cable Key, used by the military in Spanish-American War; 55: 1920s Logan SpeedX, adopted by U.S. Navy for CW operation; 56: 1941 J-41A, complete telegraph station for field operation; 57: 1941 J-51, for use with a light-signaling device.

Photos: L.R. Moreau

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Louise R. Moreau
Educated in Johnstown, Pa. and the University of Pittsburgh, Lou was licensed as W3WRE in 1953. Her interest in CW evolved into an extensive study of the history of the telegraph key. She has written extensively on the subject.

Lou is a Fellow and a life member of the Radio Club of America and is affiliated with numerous other radio organizations. She is the recipient of many awards, including the Ralph Batcher Award of the Radio Club of America, the President's Award for History of Women in Communication, YLRL, and the A.W.A. Houck Historical Award. In 1976 she was nominated to the Telegraph Hall of Fame.

Murray D. Willer
A native of Toronto, Canada, Murray is a 1935 graduate of the University of Toronto in mechanical engineering. During the war and post-war years he worked in the aircraft industry, but in 1959 he established his own company, Willer Engineering Ltd., specializing in the industrial measurement and control field.

A licensed radio amateur since 1939, he has a dedicated interest in the history of wireless and telegraphy and in restoring old instruments. His collection of wireless and telegraph keys is considered one of the largest in Canada.

Among other affiliations, Murray is a Life Member of the Society of Wireless Pioneers, a member of the Canadian Aviation Historical Society, the A.W.A., the Morse Telegraph Club, and a Senior Member of both the Institute of Electronic and Electrical Engineers and the Instrument Society of America.
THE ALEXANDERSON SYSTEM
FOR ELECTRO-MECHANICAL PRODUCTION
OF RADIO-FREQUENCY ENERGY

Glen C. Fuller, N2EXL
Kenmore, N.Y.

The development of the Alexanderson alternator represents the apotheosis of mechanical generation of continuous wave radio-frequency energy. From its inception to the completion of the twenty huge 200-kW units that General Electric produced, the history flirts with the interaction between three distinct schools of engineering. One thought in terms of power factor, kilowatts, and phase angle; the second in terms of wave length, decrement and tuning; and the third in terms of angular velocity, critical speed and proper bearing design.

The Alexander system of RF generation is a tangible artifact that weds together the interaction between scientific thought and the practicality of three separate engineering disciplines.

A consulting engineering department, staffed by a select group of engineers, was established at General Electric in Schenectady. It was conceived and headed by Charles Steinmetz, who had postulated the theories of eddy currents and hysteresis loss in iron, developed a symbolic algebra to solve complex equations, and had written a text on alternating current phenomena.¹

As early as 1900, Steinmetz was interested as a result of a letter sent to him by Reginald Fessenden describing the general specifications for a high-frequency alternator to be used for wireless transmission. Fessenden expressed the hope that Steinmetz would design such a machine and have the General Electric shops in Schenectady build it. The request was not an easy one to fulfill, but Steinmetz accepted orders for the design and manufacture of a test alternator in the early part of 1901. By spring the alternator was ready, but the results were disappointing. The Steinmetz alternator reached a maximum frequency of only 10 kHz at 4000 rpm before the rotary armature started to fly apart.²

Fessenden was not able to use this machine as he originally planned, that is, as a direct radiator of RF. However, he made the best of what he had and connected the output of the alternator to a spark gap and used the spark to excite the antenna. This combination of high-speed alternator and quenched spark obtained a frequency of 20 kHz, but the signal was noisy and the emission was still a damped wave.

On the 8th of December, 1904, Fessenden submitted a second alternator order to General Electric. The request this time was for an alternator that would distinctly function as a transmitter by itself, involving a frequency
specification of 150 kHz and a power output of 25 kW. For some reason, Steinmetz did not care to pursue the project any longer and assigned the project to Ernst Alexanderson.

Alexanderson's educational foundation paved an easy pathway for him to enter the G.E. consulting department. He was born in Sweden in 1878 and was granted an electrical engineering degree from the Royal Technical University in Stockholm in 1900. While in Germany the following year, he studied the book *Alternating Current Phenomena* written by Steinmetz. Alexanderson became so interested in the subject that he came to America with the hope of working under Steinmetz.

Following a job interview and subsequent job offer by Steinmetz, Alexanderson started to work in the testing department in General Electric in 1902. While there, he invented a power-circuit switching system and was then given a desk in the engineering department where he continued to invent under the watchful eye of Steinmetz. Alexanderson was given a free hand in the design of the new alternator. He realized the weakness of the Steinmetz design due to the limit placed on the rotational speed of the armature. Alexanderson chose to develop an inductive type of alternator using a stationary armature and a stationary field with a toothed disc rotating between them. The decision to use the inductive type of alternator was pivotal in the subsequent development of the entire Alexanderson system, for it provided the key to high rotational speeds without fear of destruction.\(^3\)

On February 6th, 1905, Patent No. 905,621 was filed. Alexanderson states in the patent that "My invention relates to dynamo-electric machines for producing alternating current of high frequency and its object is to produce a commercially operative machine capable of generating currents of extremely high frequency, such as 50,000 to 100,000 cps. In order to obtain such enormous frequency by magnetic induction, two things are obviously necessary; the distance between the poles must be extremely small and the relative movement of the poles and armature conductors must be extremely high." To attain the high rotational speed of the mechanical members, Alexanderson chose a "novel arrangement" of two discs tapered toward the periphery, and connecting the disc to a common shaft. Machining problems gave an indication that warping would occur, so a single tapered disc was developed.\(^4\)

The magnetic circuit of the inductor alternator (Fig. 1) is made up of the field yoke, the air gap, the pole face of the rotor and the field coil.

The rotor is slotted to vary the intensity of magnetic saturation as it revolves past the stationary armature. The armature coils are wound in equidistant slots on the pole face of the field yoke. The variation between the iron and phosphor bronze of the rotor creates a maximum and minima of flux density such that an alternating electromotive force is created. The emf is substantially related to the revolutions of the rotor and the number of teeth cut in the disc. The field yoke is excited by a constant D.C. source. The rotational speed of the rotor is crucial in maintaining a constant radio frequency.

Fessenden was steadfast in his theory that the eddy currents and hysteresis losses would become enormous at high speeds.\(^5\) So, when the test machines
were made, two of them were built, with one having a stationary armature made of wood and the second one having an armature made of iron. The test results were surprising.

The iron armature proved to be preferable. It gave a higher output and most certainly a better mechanical structure. The key to the success of the iron was largely due to the fact that the volume of iron that was subject to the alternating flux was quite small. The voltage of the alternator was found to be inversely proportional to the air gap. The design mean air gap was around 0.015”, but in the test the gap was reduced to 0.004” (about the thickness of a sheet of paper) causing an appreciable rise in voltage.\(^6\)

The design speed of the 100,000-Hz alternator was 20,000 rpm., and difficult mechanical problems arise in machinery of any size running this fast. It is not practical to use a rigid shaft at these speeds, so Alexanderson chose to adapt the DeLaval steam turbine principle that uses a very light, almost pencil-thin shaft to allow the disc to revolve around its own mass center. In the 100,000 Hz machine, the shaft was 1 1/4” in the center, 5/8” at the ends, and the distance between the bearings was 28 inches.

Whenever a piece of machinery is brought up to rotational speed, points of natural resonance occur. These points of resonance are called the critical speeds. Vibration at the first critical point occurs in the form of up and down motion, as if a rubber band were stretched between two points and plucked in
the center. Vibration at the second critical point acts in a violent sinusoidal twisting motion. In the 100,000-Hz machine these points occur at 1700 rpm and 9000 rpm respectively. After these two points are passed, the shaft assumes its mass center and very little vibration occurs.

It is interesting to note that Alexanderson must have been a remarkable designer, or at the very least have had the skills to go to the right mechanical people for quick solutions, and then integrate interdepartmental disciplines. General Electric was one of the foremost manufacturers of steam turbines at the time and was right on the leading edge of that technology.

In the early tests, notches were cut in the disc to serve as the flux inductor, but it was discovered quickly that windage played a big part at those speeds. Originally the slots were filled with hard solder to try to solve the problem, but under test they failed. Each filler was subject to a centrifugal force of 80 pounds. Imagine yourself lifting an 80 pound bag of cement. Then visualize 300 of those bags equally spaced and whirling on the outside edge of a disc running at 20,000 rpm. The centrifugal force of the material at the edge is 68,000 times its own weight. The solution to the problem was found to be an angular shape of phosphor bronze that was swaged into the disc and machined off to the final contour when the disc itself was machined.

At such high rotational speed it was thought that molecular air friction or mechanical abrasion by dust particles accounted for the extremely high polish on the disc after some time of operation. At a speed of 20,000 rpm, the peripheral speed of the disc is 1,000 feet per second or 700 miles per hour. Running at such high speeds presents bearing problems also, and the 100,000-Hz alternator was provided with two sets of bearings. The outside bearings supported the weight of the revolving parts and were pressure fed. The inside bearings, that is, those closest to the disc, were actually bored 1/64” over the shaft size and only functioned as the shaft touched them coming up through the critical speed. The inner bearings were also provided with a radial-thrust face to ensure correct air-gap centrality between the disc and the stationary field armature. The need for continuous oil feed was shown to be necessary because the oil-tank temperature rose 20 degrees above the ambient air temperature, and the bearing temperature itself was another 5 degrees above that of the oil.7

When it was discovered that Stenmetz’s law of hysteresis, eddy currents, and skin effect were as true at 100,000 Hz as they were at 25 Hz, it was also found that the conceptions of power factor, phase displacement, and leading and lagging currents were just as applicable and useful in the radio-frequency range. That discovery gave the go-ahead to commercial development.8 With the development of a working 100,000-Hz, 2-kW unit, Alexanderson realized that an entire system must be developed to fulfill Fessenden’s dream of mechanically produced RF. This development needed to include: 1. the design of an alternator to directly generate RF; 2. the design of a regulator that was sensitive enough to hold the speed of an induction motor constant to within a few hundredths of 1%; 3. the improvement of existing antenna systems to efficiently use the alternator’s output. That is what Alexanderson did. Not only did he develop a high-frequency alternator capable of up to 200 kW at a variety of
frequencies, but he integrated the system requirements together to form, as he put it, "a complete radio power plant."  

Let's take a look at one of the 200-kW giants. The most singular mechanical observation that is evident is that now the shaft is massive. No longer does the alternator have to be driven through the two critical periods. As a matter of fact, the shaft operates well below its own fundamental frequency of resonance. With the absence of the center bearing, it was necessary to produce a means of axial control to centralize the rotor between the two fields. In order to minimize large losses due to magnetic leakage, the air gap was maintained at 0.015" (each side). It was important to keep the gap equal because if not equal, the coils on one side could become overloaded and abnormal heating would occur.

The axial adjustment was obtained by using a labyrinth thrust bearing interconnected by a set of equalizing levers. Any tendency towards an air-gap change was automatically taken up by the equalizers. The alternator was driven by a 600-hp, wound-rotor induction motor that was operated from a 2,300-volt, 2-phase power supply. The motor was connected to the gearbox through a coupling of the Franke (some used Bartlett-Hayward) flexible type, which was delivered rough bored and finished in the G.E. Schenectady shops.

The gearbox was a double-helical step-up box with a ratio determined by the operating frequency, with its own internal oil supply, and connected to the alternator through a Franke lubricated coupling. By means of a suitable combination of motor speed, gear ratio, and alternator poles, the frequency generated by the Alexanderson alternator covered a range of 10,325 to 29,200 Hz, corresponding to a wavelength range of 29,038 to 10,268 meters.

The following tables show the wavelength and frequency of the combinations of alternator poles and standard gear ratios, using the standard motors.

A special combination of a 10-pole, 60-Hz motor with a 3.324 gear ratio was used to obtain a frequency range of 19470 to 23460 Hz, corresponding to a wavelength range of 15400 to 12780 meters, at Bolinas, California.  

Proper bearing design allowed Alexanderson to achieve critical axial

<table>
<thead>
<tr>
<th>Alternator Poles</th>
<th>Gear Ratio</th>
<th>Frequency Range in Hz</th>
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<tbody>
<tr>
<td>1220</td>
<td>3.324</td>
<td>29198</td>
</tr>
<tr>
<td>1220</td>
<td>2.973</td>
<td>26115</td>
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<td>2.675</td>
<td>23497</td>
</tr>
<tr>
<td>976</td>
<td>3.324</td>
<td>23360</td>
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<td>976</td>
<td>2.973</td>
<td>20892</td>
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<td>976</td>
<td>2.675</td>
<td>18798</td>
</tr>
<tr>
<td>772</td>
<td>3.324</td>
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<tr>
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<tr>
<td>772</td>
<td>2.675</td>
<td>14869</td>
</tr>
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</table>
TABLE 2. 8-Pole 50-Hz Motors

<table>
<thead>
<tr>
<th>Alternator Poles</th>
<th>Gear Ratio</th>
<th>Frequency Range in Hz 4% Slip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1220</td>
<td>3.324</td>
<td>24331</td>
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<tr>
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<td>2.973</td>
<td>21762</td>
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<tr>
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<td>3.324</td>
<td>15396</td>
</tr>
<tr>
<td>772</td>
<td>2.973</td>
<td>13771</td>
</tr>
<tr>
<td>772</td>
<td>2.675</td>
<td>12390</td>
</tr>
</tbody>
</table>

location, yet have a very large bearing surface to support the main shaft and keep the alternator in line. He achieved this by the use of an inner and outer sleeve. The outer sleeve was shaped like a knuckle and would pivot, within given limits, similar to a ball and socket. (See Fig. 2.)

The main bearing and labyrinth were then placed in their own carrier and allowed to be displaced axially, within given limits, in the knuckle. (See Fig. 3.)

The complete package and shaft then would resemble the sketch shown in Fig. 4.

These bearings were pressure lubricated, at pressures ranging from 5 to 15 pounds per square inch, depending on the demand of the bearing. The oil was pumped from an oil supply tank located in the base casting of the alternator. On startup, a separate 15-hp motor drove a pump until the alternator came up to speed. The separate motor pump was then cut off and the main pump, geared to the main drive shaft, supplied the oil flow. The main bearings were also water cooled by a series of copper pipes which ran through the bearing shell. The same flow of cooling water passed through a series of parallel copper tubes which were cemented in the frame alongside the laminations of the armature, thus cooling it.

![Fig. 2. Cross Section of bearing knuckle. The outside diameter rests in the bearing-support casting, while the inside diameter carries the labyrinth and main bearing.](image)
It is interesting to observe that the labyrinth technology was already well developed in the steam-turbine discipline. The decision to use that type of bearing was an excellent choice, because it allowed Alexanderson to provide axial adjustment in both directions from a mean location.\(^{11}\)

The second system requirement was met with the development of the speed regulator. Because the antenna circuit is directly coupled to the alternator-output circuit through the high-frequency transformers, any change in rotational speed of the alternator will throw the alternator out of resonance with the antenna circuit. The variable load imposed by the key-up and key-down condition of radio telegraphy causes the speed of the alternator to vary, and Alexanderson calculated that a change in speed of 1% from that necessary to maintain resonance would reduce the antenna current to one-half its full value. He realized that the speed must be held much closer than that, and did obtain, with the use of his regulator, a regulation of speed within one-tenth of one percent. With a design motor speed of 900 rpm, that control is regulating a total variation of 0.9 rpm.
The solution to the problem was found by Alexanderson in the use of a series-resonant circuit, tuned slightly above the frequency to be maintained by the alternator. One of the armature coils was tapped to supply the regulator circuit with current, and because it was a series-resonant circuit, the current in the circuit rose with alternator speed as resonance was approached. The voltage was rectified and superimposed on a voltage-regulator circuit, powered by a separate motor-generator set which supplied saturation current for a set of variable impedances in the two phases of the motor-supply circuit. Additional compensation for the load imposed when signaling was provided by a relay, operating through the D.C. control circuit to vary the line impedance.

Figure 5 is a diagram of the speed-regulator circuit. A coil in the alternator supplies a constant voltage at the frequency of the alternator. \( C_1 \) and \( P_1 \) are a capacitor and an inductor, tuned to a slightly higher frequency than the alternator was to produce. The coil \( S_1 \) is closely coupled to \( P_1 \), but not so close as to affect the tuning of the resonant circuit. \( E \) is a rectifier of the G.E. Tungar or mercury-arc type. \( M_1 \) is an auxiliary control coil of the voltage regulator. By opening and closing contact \( T_1 \), the voltage of the generator \( K_1 \) is controlled.

\( N \) and \( O \) are variable impedances connected in the two phases of the power-supply lines. They contain the D.C. control coils \( P_1 \) and the variable impedance coils \( S_1 \). \( R_1 \) is a liquid rheostat connected in the circuits of the motor rotor and was used to establish the full load "key-down" condition of the alternator. The ends of the wound secondary are brought out to the three slip rings on the motor shaft, and the series resistance is inserted.
The resistors consist of a series of iron plates which extend down into a tank. The tank is then pumped with electrolyte (usually carbonate of soda (Na₂CO₃) and water) to the desired level. A centrifugal pump, driven by a small motor, lifts the electrolyte from the lower to the upper tank. A valve in the upper tank can be adjusted to give the desired level. The continued pumping of the electrolyte from the lower tank to the upper tank and the subsequent gravity flow back causes a rapid circulation and dissipates the heat energy with a minimum amount of steaming. Liquid controls were used in motors over 200 hp because of the simplicity, large thermal capacity, and the advantage for Alexanderson of being free from definite notches or steps.¹²

The generator K₁ is driven by motor M₁, and is provided with field current from a D.C. source of constant voltage, varied by rheostat R₁. Generally speaking, when the current in impedances N and O is zero, their impedance becomes maximum. If the current through central coil Pₖ is enough to saturate the cores, their impedance becomes minimum. Any intermediate value of D.C. control current will vary the A.C. impedance of the two coils S, accordingly.

Because the circuit including C₄ and Pₖ is series resonant to a frequency slightly above that of the alternator, it will develop increased current as the motor M speeds up. This sends a D.C. component through coil M₁, aiding the D.C. already flowing in M₁. By holding control T₁ open for a longer period of time, the voltage of generator K₁ decreases. This in turn decreases the current through central coils Pₖ, and thereby increases the impedance in the powersupply circuit, decreasing the speed of the motor. When the motor speed falls, the rectified voltage through M₁ decreases, causing the voltage regulator to maintain a higher voltage on the generator (K₁) and increase the current through control windings Pₖ, and again decrease the impedance in the power supply. In operation, a mean current is maintained through the central coils Pₖ, holding the speed of the driving motor constant.

The magnetic amplifier, an iron core surrounded by two sets of windings (Figs. 6A and 6B), was Alexanderson's solution for keying the alternator. High-speed keying without destructive arcing while handling the large antenna currents was the requirement. The magnetic amplifier was a variable impedance which was connected in parallel with the output of the alternator. Its function was to reduce the voltage of the alternator and detune the antenna system when the key was open, and to allow full voltage and antenna resonance when the key was down.

Winding A is connected in parallel with the alternator (N). Coil B is an excitation winding which includes both the positive-going and the negative-going flux produced by the A winding. Because these fluxes "buck" each other, no RF voltage is produced in winding B. Looking at Figure 6A, it is clear that any tendency to introduce a voltage on one side of the coil is counteracted by an opposing voltage on the other branch.

If the flux in the control winding B reaches saturation, the effect is that the impedance of coil A becomes that of a coil without an iron core; that is to say, reaches minimum impedance. If the opposite condition is present, that is,
Figs. 6A and 6B. Fig. 6A is a simplified drawing of the magnetic amplifier, and 6B is the magnetic-amplifier circuit.

when no control current is present in coil B, the impedance becomes maximum. With the addition of condenser C1, an increase in control sensitivity is achieved, and with the selection of proper capacity an almost-linear control curve can be achieved. In actual operation, the reduction in output was from 100% to 9% of the total current in the antenna circuit with telegraphic speeds reaching 500 words per minute. Condensers C1 and C2 served as decouplers, presenting a low resistance to RF currents. These condensers had no appreciable effect on amplifier-circuit tuning.

Relay T3, along with compensating relay T2 (Figure 7), form the telegraphic signal-input circuit. The compensating relay shorts the resistance R3 when the telegraphic-input circuit is closed, decreasing the impedance of N and O and increasing the power-supply input to the motor by an amount equal to that imposed by the load, without changing speed. This lightens the load on the speed regulator, and makes it responsible only for power-supply variation.13

The magnetic amplifier was also applied as a radio-frequency modulator for telephony. The control current was modulated by a bank of piotron amplifiers, which in turn were driven by a carbon-button microphone. Using a 50-kW alternator and a modulated magnetic amplifier, telephony tests were performed between Schenectady and New York City. A variation in control current of 0.2 amperes changed the power of the antenna from 5.8 to 42.7 kilowatts—a change of nearly 37 kW. At the time it was believed that this was the greatest amount of radio energy ever controlled by telephony.14

The third requirement for an efficient antenna system resulted in Alexanderon's development of the multiple-tuned antenna, a radical departure from the types of antennas used at that time for high-power radio transmission. The
Fig. 7. A simplified circuit of a typical 200-kW station.
Fig. 8. The Alexanderson alternator at station WII, New Brunswick, N.J., showing the drive-motor end of the unit.

The object of the multiple antenna was to reduce the wasteful resistance of the flat-top aerial. It has, instead of a single ground connection, six equally-spaced leads routed through tuning inductors to the earth. The capacitive reactance of the flat top is neutralized by the inductors, making the multiple antenna the equivalent of six independent radiators—all in parallel and resonant at the same wave length. The effective wasteful resistance is much less than that of an antenna with a single ground. To maintain 600 amperes in the multiple tuned antenna at New Brunswick at a resistance of 1/2 ohm, the power required was $600^2 \times 0.5$, or 180 kW. To maintain the same antenna current with a resistance of 3.7 ohms exhibited in the flattop, 1330 kW were required. The same audibility at the receiving station, combined with less wasted power, was an important consideration from the standpoint of daily operation.¹⁴

With the fulfillment of the basic criteria for a “central power station for radio communication”, the alternators were built at the rate of two per month. Their useful life, however, was short. The demise of the great units was foretold by the development of the high-power vacuum tube. The tube was cheap to make and could be operated at higher frequencies. However, the vision of mechanical radio-frequency generation had been fulfilled, and this passage from an address given by Alexanderson in 1920 gives insight into the
Fig. 9. The alternator at station WCI-WGG, Tuckerton, N.J. Shown are the main bearing, the equalizer lever, and the RF transformers on the pipe-frame supporting structure.

Fig. 10. The control panel at station WCI-WGG, Tuckerton, N.J. The speed-regulator board is the second panel from the left.
nature of the man who made it possible.

"Radio achievements are often referred to as belonging in the realm of mystery, and it is indeed wonderful that we are now able to speak with a voice that carries through empty space across the oceans. Whenever knowledge conquers a new force of nature for the use of humanity, it ceases to be a mystery, but the pursuit of the knowledge makes an even greater appeal to the imagination."
NOTES AND REFERENCES


3. Alexanderson was not the first to use the inductor alternator at high frequency. See B.G. Lamme, “Data and Tests on a 10,000 Cycle-Per-Second Alternator”, *AIEE Transactions*, Vol. 23, May, 1904, pp. 417-428.


$$1 \mu = \frac{3570}{\sqrt{\lambda \mu f}}$$


Fig. 12. The gearbox and separate oil-pump motor of the alternator at station WQR-WSO, Marion, Mass. Note the flexible coupling between the main driving motor and the gear box.

Fig. 13. A spare rotor covered with cosmoline. Note the main journal, protected in paper, and the labyrinth on the left.
Glen C. Fuller
Glen, an active A.W.A. member since 1980 and a second-term member of the Board of Directors, also served as an assistant curator of the A.W.A. museum. After becoming a licensed amateur in 1964, Glen developed an interest in early wireless and telegraphy, including researching the mechanical methods of radio-frequency generation and the life and works of Steinmetz. His strong background in historical wireless, coupled with his vocation as a tool and die maker, are currently being melded together in his construction of a working replica of Branly's Tripod Detector Receiver of 1908.

Photos: A.W.A. Museum
MESSAGE FROM THE EDITOR

With this issue of the A.W.A. REVIEW I am retiring as its Editor. I hope, and believe, that the publication of the first three issues of the REVIEW has been a worthwhile effort, in that it has helped to preserve some of the history of radio brought to light by the authors.

Not all the work has been easy, but neither has it been too difficult. In many respects I have enjoyed it, and I have learned a lot. You can’t edit unfamiliar material without occasionally encountering things you think are wrong. You then do independent research to determine the truth. Memory can play tricks, and history that isn’t correct is fiction.

The story of the development of radio communication will occupy the efforts of historians for many years to come. I hope the REVIEW will become a permanent publication of the ANTIQUE WIRELESS ASSOCIATION, and will continue to document those efforts.

Robert M. Morris, W2LV