• The Regency TR-1: 50 Years Later, by Paul R. Farmer
• A History of the Kodel Radio Corporation, by John E. Leming, Jr.
• The Evolution of the Submarine Telegraph With an Extensive Bibliography, by Bill Holly
• Broadcast Receiver Manufacture by General Electric and Westinghouse in the First Decade of RCA, by Robert Murray
• The Evolution of the National HRO and its Contribution to Winning World War II, by Barry Williams
Table of Contents
VOLUME 17 - 2004

Foreword...........................................................................................................iii

The Regency TR-1: Fifty Years Later
by Paul R. Farmer..........................................................1

A History of the Kodel Radio Corporation
by John E. Leming, Jr. ..........................................................31

The Evolution of the Submarine Telegraph,
With an Extensive Bibliography
by Bill Holly........................................................................73

Broadcast Receiver Manufacture by General Electric
and Westinghouse in the First Decade of RCA
by Robert Murray...........................................................107

The Evolution of the National HRO and Its
Contribution to the Winning of World War II
by Barry Williams...........................................................145

Cumulative Table of Contents and Author Index
for Volumes 1 through 17 of the AWA Review..................203
Foreword

The AWA Review Volume 17 contains an unusually diverse collection of articles. In time frame, they run from Bill Holly’s extensive documentation on nineteenth-century submarine telegraph cables to Paul Farmer’s study of the 1954 Regency TR-1, the first commercially offered transistor radio. The TR-1 story leads because 2004 is the 50th anniversary of the introduction of the consumer transistor radio—a watershed in the evolution of radio manufacturing in the United States.

Much has been written about radio companies such as Atwater-Kent and RCA, but in this issue, John E. Leming, Jr. relates the history of a heretofore poorly documented company—The Kodel Radio Corporation. John has done careful research, including interviewing a descendent of the founder of Kodel, and now we can know “the rest of the story” about this 1920s Cincinnati-based radio and power supply manufacturer.

Robert Murray’s detective work clears up some long-standing mysteries about which company, General Electric or Westinghouse, manufactured the receivers sold by RCA in its first decade. Living in Canada and being able to compare U.S. and Canadian versions of RCA’s receivers helped Bob sort out the facts.

Communications receiver collectors have long been fond of the National HRO. Barry Williams’ article provides important details about the evolution of this classic receiver, as well as the fascinating story of how it helped to win World War II for Britain.

My thanks to all five authors for their hard work and significant contributions to the history of electronic communications. Enjoy reading this issue!

I hope more readers will consider writing for The Review. If you have an idea for an article, please contact me before you start. I can help you decide whether your topic would be appropriate for The Review, and provide time-saving tips on things like preparing illustrations and reference formats.

Brian Belanger, Editor
5730 Avery Park Drive
Rockville, MD 20855-1738
Email: bcbelanger@aol.com
(301) 258-0708
The Regency TR-1
Fifty Years Later

By Paul R. Farmer

© 2004, Paul R. Farmer

The introduction of the first transistor radio, the Regency TR-1 (Fig. 1), was announced fifty years ago by Texas Instruments (TI) and IDEA Corporation on October 18, 1954. It was a technological and cultural watershed for manufacturers of consumer electronics equipment and for future users of all kinds of electronic products, in the home, industry, the military, and government. The paradigm shift from vacuum tube to semiconductor technology had begun in earnest. It would take almost a generation to complete; but it had begun.

To vintage radio collectors who grew up in the era of vacuum tube radios and who remember all of the exciting radio programming before television became the dominant entertainment and information medium, fifty years does not seem like such a long time. But for comparison, consider that the period of time from the beginnings of home vacuum tube radio reception of regular commercial broadcasting in the early 1920s until the 1954 introduction of the transistor radio was

Figure 1. Regency TR-1: The world’s first marketed transistor radio (author’s collection).
just over thirty years. To be sure, the vacuum tube did not give up its dominance of radio for another ten years and would never become just a footnote in history, but with the commercial application of the transistor, an even more far-reaching innovation had been launched.

The First Transistor Radio Was Not a Sony

To the surprise of many, even some within the vintage radio collecting community, the first transistor radio to market was not a Sony (Fig. 2). For some reason, the public especially has the notion that Sony introduced the first transistor radio. The best explanation for this misinformation probably has to do with the way the Japanese in general, and Sony in particular, quickly came to dominate the transistor radio market and eventually the entire consumer electronics industry. And, the name Sony became synonymous with consumer electronics innovation. Besides, who ever heard of IDEA (Industrial Development Engineering Associates)?

It was IDEA of course, maker of TV antenna boosters (set-top boxes) in Indianapolis, Indiana, that built and marketed the first transistor radio, the Regency TR-1. IDEA could not have done so had Texas Instruments not decided to pursue the development of such a radio, industrialized the production of transistor devices, and launched a hurry-up effort to design, build, and test a commercially viable transistor radio circuit. But even before that, the transistor had to be invented.
Bell Laboratories technical staff members William Shockley, John Bardeen, and Walter Brattain (Fig. 3) were largely responsible for the invention of the transistor, announced to the world on July 1, 1948. It was a germanium point-contact device, and they each, Shockley, Bardeen, and Brattain, won the Noble Prize in Physics in 1956 for their profound achievement. Bell Labs became the licensing agent for the transistor and, beginning in the autumn of 1951, licensed its production by numerous companies for just $25,000 (an advance on royalties) per license. Texas Instruments, Raytheon, and dozens of others purchased licenses. Notable among earlylicensees was the Japanese company Sony. IDEA did not need a license; they never manufactured transistors.

A mass-market transistor radio was not the first consumer application for the Bell Labs invention of an amplifying semiconductor device, i.e., the transistor. Transistorized hearing aids went into production by Sonotone and Zenith in 1952/1953. While the potential market for hearing aids was far smaller than for transistor radios, there were several advantages. The amplifying
components in hearing aids (formerly miniature vacuum tubes) had only to operate at audio frequencies, and the circuit design was relatively simple. The first production transistors performed satisfactorily at audio frequencies, but it was a while before their range was extended to radio frequency applications with adequate performance. In fact, once the transistor had been invented, consistently producing transistors that would perform at acceptable levels in RF applications was the number one challenge to the development of the transistor radio. The rejection of a high percentage of transistors for low performance, especially at radio frequencies, was a major factor that kept transistor component prices high and transistor radios costly right through the mid-1950s.

Compared to radios, it was easier for manufacturers to market hearing aids at high profit margins, because of the more critical need for them. Transistor hearing aids could be produced sooner, at lower cost, and yet sold to the public at higher prices than transistor radios. Zenith’s first transistor hearing aid sold for over $100 in 1953. A hybrid micro-tube and transistor Sonotone sold for over $200 in 1952. The transistor radio was a discretionary expenditure for the public, but the hearing aid was a practical necessity for the seriously hearing-impaired.

Early in the 1950s, Texas Instruments recognized that the reliable mass production of transistors with reasonable performance parameters was not far off. Once they were convinced that they could develop and improve transistor production, the way was open for them to design a transistor radio and bring it to market. Consistent production of transistors having the desired performance was a problem at first that kept the cost high for a while, but TI probably underestimated the amount the public would be willing to pay for the product that they were about to develop. The introduction of the world’s first transistor radio at the seemingly steep price of $49.95 was very well received. Sales were a great success. Orders exceeded radio inventories and production capacity, but at less than $50 per unit, the profit margin for TI’s production and marketing partner, IDEA, was slim. As the quality of mass-produced transistors improved and costs declined, profit margins increased and transistor radios could be priced lower still. Other manufacturers got into the game and transistor radio sales exploded for American and then Japanese companies. It is not likely that anything could have been done to prevent the Japanese from completely dominating the industry by the 1960s. It would not be the
last time that lower Japanese labor costs, price competitiveness, and superior styling would win out in an industry segment initially dominated by the United States.

The first transistor radio was a wonderful demonstration of a new technology that, once recognized and perfected, would have revolutionary impact well beyond the consumer electronics industry. While the life and culture-changing implications of transistors in home and personal radios were significant, the ultimate impact was perhaps more profound for a much broader spectrum of communications, military and space applications, and especially for the infant computing industry. Considering the developing miniature and sub-miniature vacuum tube technology, there was relatively little of serious importance in broadcast radio reception that was new as a result of the invention of the transistor. Hearing aids and coat pocket portable radios could be made a little smaller with transistors, compared to sub-miniature tubes, and battery life could be significantly extended, reducing the cost of operation. But in the realm of two-way mobile communications, advanced military weapons systems, space satellites, and especially high-density computer processing power, there were no good substitutes for semiconductor technology.

The significance of the pocket portable transistor radio in general and the Regency TR-1 in particular as a demonstration of advanced technology for more important industries is best exemplified in the oft told anecdote regarding Thomas Watson, 1950s CEO of IBM, and his chief engineers. Watson recognized the merits, nay imperative, of moving the IBM-led computing industry from one based upon vacuum tube technology to one based upon semiconductor technology. At some point he decreed that IBM would manufacture no computers using vacuum tubes after June 1, 1958. His engineers, however, resisted. When he tired of their excuses and complaints regarding progress in the conversion to the new technology, he bought hundreds of Regency TR-1s and handed them out whenever his subordinates complained about the strategy.

**Developing the TR-1 – First Radio Application of the Transistor**

Fifty years ago a few young men saw the financial potential of solid-state semiconducting devices and had the competitive drive to be first. They launched a “secret” crash project to bring that device into
the home of every American, in the form of the world’s first transistor radio. Those men worked at Texas Instruments, not yet a household name but nevertheless the company that would be most responsible for moving the transistor radio from concept to reality.

By the early 1950s Texas Instruments had the ambitious goal of becoming a major manufacturer of semiconductor devices and a much larger company. First they encountered the technological hurdle of establishing an effective and efficient manufacturing process for transistors. Next there was the need to establish an entry product that would create a market for Texas Instrument transistors and demonstrate the practicality of using them in place of vacuum tubes in any number of product applications. The transistor radio would be that entry product and the plan worked. Texas Instruments went on to become, for a time, the world’s largest producer of semiconductor devices.

In the spring of 1954, Texas Instruments decided it could wait no longer to start the transistor radio project. The TI team, headed by design engineer Patrick Haggerty, needed to get the transistor radio to market by November in order to take advantage of the lucrative Christmas sales season and to have a decent chance of beating the competition. Project secrecy was critical if TI was going to be first. But it was not going to be an easy feat. As told in “The Secret Six-Month Project” in the December, 1985 issue of IEEE Spectrum, “This was a tall order for a [R&D] group that as yet had no experience in transistor circuit design, no transistors capable of operating reliably in a radio circuit, and no facilities for mass-producing such radios.” It really was going to be a crash project.

The first breadboard to demonstrate concept feasibility was designed and built in little more than a long weekend by a Texas Instruments team that included engineers Paul Davis, Roger Webster, Mark Campbell, and Ed Jackson. It contained eight transistors. But the manufacture of transistors was so expensive at this point that the circuit had to be redesigned to operate with fewer. The TI design team eventually worked out a superheterodyne circuit that used six transistors: oscillator, mixer, two IF stages, detector, and audio output. It was not going to be an exceptional performer with transistors that provided little more than 20 db gain each at the intermediate frequency of 262 kHz, but it would have to do.
TI's next step, and it was an important one, was to find a manufacturer to design and build the set to their specifications. As it turned out, no major radio manufacturer would touch the project. All apparently thought the effort was premature. It is amazing that Texas Instruments had to turn to a little post-war start-up outfit in Indianapolis run by a couple of engineers who left RCA to build their own electronics business out of a garage. But the timing was perfect for IDEA. By 1954 the market for their TV boosters was losing its legs as TV stations proliferated beyond the major metropolitan markets, putting more and more home TV receivers within acceptable range of a transmitter.

Needless to say, IDEA accepted the project, handing it to Richard Koch, design engineer for their Regency Division. IDEA’s job was to design, mass produce, and market a transistor radio based upon the preliminary TI circuit design, using TI transistors and parts from a host of other suppliers. The TI specifications required that the case be no larger than 3 by 5 by 1¼ inches (so that it could be advertised as the world’s first pocket radio) and that the retail price be no more than $49.95 (so that it would not be completely out of reach for Christmas shoppers). Both of these requirements were huge challenges for Koch and his team at Regency.

Koch started with the cost issue. TI’s transistors were still too expensive to use more than four in the radio, if it was to be profitable to sell the little set for less than $50. The TI circuit had to be reduced to just four transistors, no matter what other cost cutting might be realized. The first transistor to go was easy; Koch substituted a Raytheon germanium diode for the transistor detector, with no loss in performance. After much thought, he figured out how to combine the oscillator and mixer stages in the TI design into a single-stage converter, similar to the economy that had been worked out for tube-type superheterodynes years before. This was a first for semiconductor technology, and it earned him a patent in 1959. He was also able to eliminate several resistors and reduce battery drain by designing an IF biasing circuit that earned him another patent. Fig. 4 is the circuit schematic and Fig. 5 is the eventual chassis layout for the production Regency TR-1.
These changes to the TI design were going to make it a little easier to fit everything into a diminutive plastic cabinet, the molding of which IDEA subcontracted to another Indianapolis firm, Argus Plastics. But it was still not going to be easy. Most of the required components (tuning capacitor, electrolytic capacitors, transformers, loop antenna, speaker, etc.) were not available anywhere on the sub-miniature scale required for this product. It was a major challenge to get a multitude of component manufacturers to take on the design, tooling, and production of each of these items in time to make the project come together on schedule. Numerous component suppliers were successfully lined up, but in the end Regency had to design and build a few of the components itself.

Fig. 6 is a design prototype from the TR-1 project. It has a bench-fabricated, clear acrylic case, and uses an Emerson tuning knob. It is quite compact.
and appears to have only four transistors, suggesting that it does not represent the earliest TI designs. Nor does it yet represent the final parts layout and cabinet proportions and design of the Regency production model.

Packaging – The Cabinet Design

IDEA contracted the design of the plastic cabinet for the Regency TR-1 to the Chicago firm of Painter, Teague, and Petertil. Victor Petertil was awarded a patent for the perforated grille design ultimately used for the TR-1 (Fig. 7), and for a second, similar, slotted grille design (Fig. 8) that was never used for a production model. The sequential patent numbers (176,480 and 176,481) for these two designs demonstrate that the patent requests were submitted together. Both designs have clean lines and a simple, yet modern appeal...not quite art deco, not jet age, not post-modern, but not pedestrian either.

It is possible that the design team presented competing stylistic designs for IDEA’s selection, but other than the two design patents there is no documentation to support this notion. If
the Regency Division did choose between the two Victor Petertil designs, their decision could have been based upon the Regency team’s own sense of aesthetics, lower production costs that may have been associated with the simpler grille, or an ability to mold the simpler grille with thinner plastic. A thinner plastic cabinet front may have been an issue. The 1985 IEEE article states that the Chicago industrial design firm’s first design was rejected because the case would not “hold everything and still be small enough,” and that Regency’s Koch was struggling with “unreasonably close tolerances.” The article states that the design firm had to come up with a second design. So it is possible that the cabinet design that received the second registered patent number (the slotted grille) was actually designed first (and rejected), and that the cabinet design that was accepted and used for the TR-1 was designed slightly later but received the first patent number in the two-number sequence. (The patent number sequence for designs submitted together would not necessarily reflect the chronological order of the designs.)

There are no known examples of a TR-1 case with the slotted grille design. It would have been an unnecessary extra expense and delay to tool up molds for prototype case production by Argus Plastics for each of two, or potentially more, different designs. According to John Pies, one of IDEA’s two founders, prototype TR-1 cases were machined, not molded. But it is not entirely clear whether he is referring to early, bench-produced cases for prototype circuit designs, or late, pre-production prototypes based upon the Petertil case design patent drawings. Those drawings do not contain the dimensional information that would have been required to determine chassis fit or to build prototype cabinets. There would have been more detailed drawings from the Petertil firm for any case design presented to
Regency, and for any case prototypes that had to be built for presentation. Given the very close mechanical tolerances, it is unlikely that Koch’s Regency team would have made a decision based upon drawings alone. All of this suggests that a machined-case prototype based upon the slotted-grille patent design probably exists.

The Transistor Radio – Not Without Cultural Implications

While not as significant as the coming semiconductor transformation of computer technology (the full effects of which are still unfolding), the transistor radio had its own implications for American culture. This was a two-way proposition. Aside from strictly technological advances, American cultural evolution readied America for the transistor radio, and the transistor radio helped steer American culture through, and out of, the prosperous 1950s and tumultuous 1960s.

Portable consumer radios in America go back almost to the beginning of commercial radio broadcasting itself. But by the late 1930s and then especially in the postwar era, certain radios, aided by technical advances, including the introduction of miniature vacuum tubes with their reduced power requirements, began to become more and more portable. AC/DC sets were smaller and lighter than early battery sets or AC sets with their large power transformers. The introduction of plastic cases reduced size and weight more, and some of the smaller sets started to sport handles on top so that they could be conveniently carried from room to room. Emerson was one of the leaders in this category, and by the time the Regency TR-1 was about to be introduced, Emerson was selling well-performing little coat pocket portable sets employing four miniature tubes, powered by dry batteries. Some of these sets were smaller than some of the yet-to-be-built early transistor portable radios, and not much bigger than the TR-1. Their small, colorful plastic cases are a source of confusion for some collectors today who (if they are not focused on these mini-tube portables) may mistake them for transistor radios.

So in many ways, the consumer radio industry was headed in the direction of the transistor radio long before the transistor was invented or even conceived of by most of those in the industry.

American culture at mid-century increasingly valued mobility, convenience, recreation, and a sense of socio-economic success. The portable radio complemented the life styles of the growing middle and
upper classes who could afford them and who could afford to take them on driving vacations to the beach. At the same time, before the complete dominance of television, American youth were experiencing a revolution in popular music. High fidelity was not a requirement for the enjoyment of this new Rock 'n' Roll sound; portability was. Twentieth Century American culture created more than one market for the portable radio, especially the transistor portable radio.

Much like television was about to do, the transistor portable radio changed the very culture that it embraced. Youth access to the new music was just what that music needed to fully explode onto the American scene. The music influenced the way youngsters grew up, and the transistor radio helped make it happen. It was a constantly available source of news, weather, and sports as well for a generation of Americans. But with its civil defense markings, the transistor radio also reminded all Americans of the Cold War’s threat to civilization. The transistor radio itself became an American cultural icon. Along with other portable radios, it is celebrated as such in Michael Schiffer’s outstanding tome, *The Portable Radio in American Life.*

**The TR-1 – First in a Family of Related Sets**

The Regency TR-1 and all of its variants form a large and interesting family of almost pocket-sized transistor radios. There are make, model, and color variants that total at least thirty distinguishable sets, not including the differentiation of early, middle, and late variants of the TR-1 proper, nor several additional oddities (discussed below). What all of the variants have in common are similar chassis built by Regency; similar-sized vertical-oriented cabinets made for Regency (most are nearly identical); and a general family resemblance. The variety of models and colors for the TR-1 family of radios makes it an especially attractive, specialized interest for today’s collectors of transistor radios.

Regency TR-1 production and sales began with a four-color offering: bone white, cloud gray, mandarin red, and black. The retail price was $49.95. Accessories (leather carrying case, earphone, battery) were extra. There was an impressive amount of print advertising for Regency products, which helps to document the progression of radios, dealers, and prices. Fifty dollars was a considerable sum for a portable radio of very marginal performance in 1954. Well-playing miniature tube portable radios could be had for as little
as $10. Much of Regency’s advertising for the TR-1 emphasized the technological significance of the first transistor radio, cast it as an upscale personal luxury item for a sophisticated audience, and bragged about its high performance, making shamelessly boastful claims such as, “...reception and tone better than most radios many times its size.” This was not just an exaggeration; it was a demonstrably false, willful misrepresentation.

Nonetheless, TR-1 advertising was often quite glamorous. It is interesting today for its information content and graphic artistry, and is collectible in its own right. Figs. 9 and 10 are two of my favorite ads. The TR-1 debuted in two upscale markets, New York City and Los Angeles. The product was very well received and sales went national.

A number of obvious, sequential modifications to the TR-1 allow collectors, in association with the sequence of serial numbers (found on the chassis), to classify these radios as early or late variants; or even early, middle, and late variants. Features that characterize early examples include a logo that was molded into the front of the plastic case, short tuning alignment lines both above and below the dial, and an adjustment set screw in the back of the variable tuning capacitor that required a small circular depression in the inside of the back half of the plastic case because of the tight clearances.

By early 1955 small changes were already being introduced. The label inside the back cover was enlarged. A coin slot was added to the bottom of the case to aid in removing the plastic back. An alignment dot was added just below the ON-OFF/volume thumb wheel to mark the OFF position. The metal battery clips were modified from plain ends to folded ends. Beginning about mid-year, the molded-in logo was given up in favor of a stamped-on logo (still in gold) and the tuning alignment line under the dial was eliminated. The tuning capacitor lost its set screw, followed somewhat later by the disappearance of the circular depression in the inside back of the case. A slightly redesigned logo for the next Regency model, the TR-1G, began appearing on the TR-1 in the autumn of 1955. There are also early and late variants of the leather carrying case (Fig. 11) for the TR-1. The early variant had a circular pattern of holes in the front, whereas the late variant had a square pattern of holes.

While serial numbers show a tendency to correlate with the staggered progression of changes (described above) in the TR-1,
Figure 9. One of many Regency TR-1 ads that targeted an upscale market.
chassis were not necessarily used in the precise order of their manufacture, and many malfunctioning TR-1s were returned to the factory for service, where some probably received new chassis for bad ones, and even new plastic cabinet parts or entirely new cases for broken ones. Add to this the practice by some collectors of making their own substitutions among sets for broken cabinets and non-functioning chassis, and the difficulty of establishing the significance of the sequence of serial numbers is compounded.

Of great interest to collectors is the introduction of additional colors for

Figure 10. Another classic Regency TR-1 ad.

Figure 11. Leather carrying case for the Regency TR-1 (author's collection).
the TR-1. Forest green and mahogany sets, both marbleized, were available almost as early as the original colors. They must have been produced in smaller numbers though, because they are much scarcer today than sets in the original four colors.

Pearlescent TR-1s – The Collector’s Holy Grail

Far scarcer still are a series of sets advertised in five “pearlescent de luxe finishes” of pearl white, meridian blue, pink, lavender, and lime. The pearlescents are variably marbleized and highly translucent. The finish has great depth and iridescence, with a soft glow of refracted light (Fig. 12). They were offered at a premium price of $54.95. Very few of these now extremely desirable pearlescent sets appear to have been manufactured and sold, and scarcely any have made it into the hands of today’s collectors. I can document three extant pearlescent pearl whites, three meridian blues, one lavender, and one pink, but no lime examples. Interestingly, some Regency advertising mentions only four pearlescent colors, excluding the lime. This, combined with the absence of a confirmed lime example, leads collectors to question whether or not a set was ever produced in that color. The pearlescents are some of the most sought-after radios from the TR-1 family. The appearance of any pearlescent TR-1 is a noteworthy event, but the appearance of a lime example would capture the attention of every serious TR-1 collector.

TR-1 Oddities – Strange and Wonderful Collectibles

Regency made a few TR-1s with clear acrylic backs (Fig. 13) in place of the usual opaque ones. These were

Figure 12. Pearlescent (meridian blue) Regency TR-1 (David Mednick collection).
almost certainly intended as sales-boosting dealer display items to show off the miniature transistorized circuitry inside, for the benefit of prospective buyers. Who knows whether shoppers were ever able to buy any of these specialty sets, but several have turned up in the extant population. Even more interesting are a small number of completely clear-cased TR-1s (Fig. 14) that appear to have been built as both pre-production prototypes and post-production novelties, probably to promote the transistor radio concept within a narrow segment of the industry. Texas Instruments, the Smithsonian Institution, and at least one collector have examples of this rare set.

Movie producer Mike Todd acquired a few TR-1s with specially made, book-like storage cases to commemorate his movie, *Around the World in 80 Days*. He presented these to friends and had their names engraved

**Figure 13.** Clear back TR-1, a display radio for Regency dealers (Steven Reyer collection).

**Figure 14.** Clear-cased TR-1, apparently a pre-production demonstration prototype and/or post-production promotion novelty (Smithsonian collection).
inside the book cover. Surviving examples are known to exist for Arthur Miller, Shirley MacLaine, and Lou Berg. There is nothing unusual about the radios, but the “Mike Todd book cases” are rare. It is not clear whether Regency made these book-like cases to hold the radios, or if Mike Todd commissioned someone else to make them.

There are reports of TR-1s with rhinestones embedded in the grille, between the little round grille perforations. A pearlescent pearl white TR-1 (Fig. 15) appearing on eBay in 1999 had this embellishment (with many of the rhinestones missing), but I have seen no other like it. In April 1956, the Dallas Times Herald carried a Neiman Marcus ad for “jeweled” iridescent [pearlescent] Regency TR-1s, possibly a reference to the rhinestones seen on the eBay example. Neiman Marcus is just the kind of innovative, up-scale, fashion-conscious retail outfit that might have carried something as off-beat as a rhinestone-jeweled transistor radio. Interestingly, the eBay seller of the rhinestone TR-1 was located in Garland, Texas, a suburb of Dallas. The only retail stores for Neiman Marcus in 1955/56 were in Dallas and Houston. If Neiman Marcus, and only Neiman Marcus, had Regency make just a few of these specialty items, that would explain their extreme rarity today.

Figure 15. Rhinestone embellished, pearlescent (pearl white) TR-1 (ex-Clay Lightfoot collection).

Figure 16. An engraved pearlescent (pearl white) TR-1 (Bill Overbeck collection).
Alternatively (but less likely), the rhinestones might have been a decoration added by a jeweler after the eBay set left Regency. Some jewelers were retailers of transistor radios in the earliest years of transistor radio sales. Another pearlescent white TR-1 (Fig. 16) carries a gold-filled engraving of the words “The Carters” on the front of its cabinet. This is the kind of work that may have been executed by a jeweler for a customer, and probably was in this example. Perhaps the Neiman Marcus use of the term “jeweled” was just a reference to the jewel-like appearance of the translucent pearlescent plastic cabinet, but I don’t think so.

Finally, there is at least one example of a TR-1 with a chrome-plate-finished case (Fig. 17). This is another example of a final case treatment that may or may not have been applied by Regency. I am not aware of advertising that mentions a chrome finish. The Regency TR-1 was so well recognized as a technologically important, innovative new product, that some retailers and a few owners may have taken it upon themselves to celebrate the new product by adding their own embellishments to further enhance its already handsome design.

**Beyond the TR-1 Itself – The Family Grows**

The Regency TR-1G (Fig. 18) was introduced in May 1955, well before sales of the TR-1 were discontinued. Little changed from the TR-1, the TR-1G sported a lower price tag of just $39.95 retail, reflecting reduced production costs. A PNP transistor was substituted for the NPN grown junction transistor in the audio output stage of the TR-1. The main external distinguishing feature of the TR-1G is the re-

![Figure 17. Chrome plate finish TR-1. Origin of the finish is uncertain (unattributed collection).](image)
designed look of the tuning dial and some new colors. The TR-1G was offered in black, gray, coral, turquoise, and yellow. There was a $5 premium for all but the black color and it appears that about sixty percent of the sets were produced in black as a result. Yellow sets are rarely seen and probably represented only about three percent of TR-1G production.

The introduction of the Regency TR-1G just six months after the debut of the TR-1 itself demonstrates Regency’s eagerness to move their production of transistor radios to and through a line of “new and improved” models. This common marketing strategy attempts to keep the models changing, even if only superficially, in order to attract new buyers and interest existing owners in buying the next, “better” set. This is not unlike the strategy of manufacturers of tube radios from the early 1920s onward. Many radio models were produced for only a matter of months; few were produced for more than a year or two without change. In some cases new sets were technically better, but sometimes they were just re-styled. In the case of the TR-1G even the re-styling was minimal. The fact that Regency continued to produce the TR-1, promote it as a technological first, and offer it at a higher price than the TR-1G suggests that the very first transistor radio had a premium appeal well before it became a vintage collectible.

Externally, Regency’s next model, the TR-4 (Fig. 19), once again simply involved re-styling the dial and offering a reduced selection of just three colors: black, ivory, and red. Like the TR-1G, the TR-4 cabinets came out of the same molds that Regency used for the TR-1. But more changes were made to the electronics, most notably an increase to the industry standard 455 kHz IF (from 262 kHz used in the TR-1 and TR-1G), and conversion to the 9-volt battery that would
become an enduring standard for transistor radios. Both of these changes were made practical by improvements in the quality of transistors produced by Texas Instruments.

Off-Brand Members of the TR-1 Family – Bulova, Mitchell, Mantola

Like so many radio manufacturers, IDEA produced radios for other companies, often by doing little more than re-branding their Regency sets with the name of another manufacturer or retailer. As a consequence, there are several early transistor radios sold under the Bulova, Mantola, and Mitchell names that rightly belong to an extended Regency TR-1 family.

In 1955, IDEA worked out a deal with Bulova to re-brand the Regency TR-1 with the Bulova name and logo. That same year, Sony, perhaps aware of the Regency deal, almost worked out a similar arrangement with Bulova regarding Sony’s introduction of the TR-52, their planned entry into transistor radio production. Sony was looking for someone with an established retail network to sell the sets in the United States, and Bulova was willing to buy 100,000 of them. But Bulova required that the sets carry the Bulova brand name. It was a big, important contract for Sony, but after some soul searching they balked at the branding requirement and the deal fell through. This was fortunate for Sony on two counts. In the long run, Sony was better able to establish its own brand and reputation by adhering to a policy (unlike Regency’s) of not re-branding its products. And, as it turned out, it was discovered that the TR-52 had a serious technical problem that wasn’t immediately apparent. As a result, the Sony TR-52 never went into serial production, even for the Japanese home market. Sony would have had a problem trying to fill the Bulova order.

Figure 19. Regency TR-4, another new dial and a more highly-modified circuit (author’s collection).
IDEA’s re-branded Regency TR-1 for Bulova was designated the Bulova Model 250. It uses a TR-1 chassis and plastic cases essentially identical to the Regency TR-1 cases, but without an earphone aperture, and of course with the Bulova name and logo in place of Regency’s. The plastic Bulova 250 was offered in just two colors: black and ivory. But the 250 was also produced in an unusual brown leather over plastic case (Fig. 20). About two thirds of Bulova 250 production appears to have used the ivory cabinet. The leather sets are rare.

IDEA’s shift to a stamped (rather than molded-in) name and logo for the Regency TR-1 was apparently instituted to permit the same molds to be used for production of the Regency TR-1, TR-1G, and TR-4, as well as the Bulova 250 and Mantola M-4D (see below).

Three unusual off-brand versions of the Regency TR-1 were built for Mitchell and designated Models 1101, 1102, and 1103. All are scarce. Like the Bulovas they use the TR-1 chassis, but their cases are unlike any others in the TR-1 family. The Mitchell branded TR-1s have hinged leather cases and perforated metal grilles. The three model numbers represent three different leather treatments: the 1101 Suntan (Fig. 21); the 1102 Alligator; and the 1103 Antique White. There is no evidence that the chassis were built and the radios assembled by anyone but Regency.

The last of the off-brand Regency variants from the TR-1 family is the Mantola M-4D, a re-branded Regency TR-4. Mantola

Figure 20. Bulova 250, a re-branded TR-1. This one features an unusual leather on plastic case (Sara Lowrey collection).
labels with the inscription, Madison Industries Products Development Co., Lawrence, Indiana, are found inside Mantola M-4D’s. Regency is known to have manufactured radios for Madison Industries. The TR-1 and its successors were built at Regency’s plant in Lawrence, a small town within metropolitan Indianapolis. In all likelihood, “Madison Industries” was nothing more than a unit of or pseudonym for IDEA’s Regency Division.

Regency used the TR-4 9-volt chassis and the usual TR-1/1G/-4 plastic cases for the Mantola M-4D, but the set sports a very space-age, atomic dial (Fig. 22). The IDEA management team was aware of the potential market for transistor radios among Americans who were concerned about the direction of the Cold War and the possible need for civil defense information in a nuclear attack. The Mantola M-4D dial may have been designed with this market in mind. The M-4D was offered in black, red, and ivory. They were sold in B.F. Goodrich stores. All are scarce.

There have been a number of rumors that report that Regency re-branded radios from the TR-1 family for several additional companies. None of these reports has been confirmed.

Figure 21. Mitchell 1101, another leather-cased, off-brand TR-1 (Eric Wrobbel collection).

Figure 22. Mantola M-4D, a re-branded TR-4 with atomic dial design (author’s collection).
A TR-1 Family Census

Table 1 lists all of the major known variants of the Regency TR-1 family. The table includes a frequency of appearance count (census) taken from eBay for the period from October 30, 1999 through September 27, 2000, approximately 11 months inclusive. Data from this eBay census combined with one other critical datum, the total number of TR-1s reportedly produced by IDEA, permits estimates of the production numbers for every family variant, including individual colors. By making a few additional assumptions, I have estimated the current rarity of each variant, including a specific estimate of the number of surviving examples for each variant.

Keep in mind that the census counted a fairly small sample of just 108 examples of the many TR-1 family variants. Consequently, some of the estimates in the table likely represent only a rough approximation of the actual numbers produced and extant. Some of the estimates for the least frequently seen variants have been adjusted as a result of my observations outside of the census. I hope there will be a future opportunity to revise these estimates based upon a larger sample.

The number of TR-1s produced has generally been estimated to be about 100,000. In a paper published in conjunction with Texas Instrument’s 25th anniversary observance of the transistor radio in March 1980 (available on the Internet), TI design engineer Patrick Haggerty stated that IDEA produced between 104,000 and 105,000 Regency TR-1 radios. Serial numbers for the TR-1 begin with SN 1001 and range all the way to SN 127516 at least. There is an apparent break (based upon my observations) around that number, until they pick up again from 140042 through 141985. At the time I wrote this article, ninety serial-number records were available. As more serial number records become available, perhaps it can be confirmed that there is in fact a break in the sequence of serial numbers around 130,000.

The explanation for serial numbers as high as 127,000 and even 141,000 and how to square that with Haggerty’s 1980 statement is a nagging question. But it should be noted that Richard Koch, of Regency, reported that the production chassis failure rate under test was high; as high as fifty percent at first. So although Regency may have built 127,000 or more chassis, given a high reject rate and the need to build extra chassis as replacements for some of the substantial number of sets that came back to the factory for repairs, it is possible
Table 1.

<table>
<thead>
<tr>
<th>Model</th>
<th>Color Variants</th>
<th>eBay Count</th>
<th>Percent of Model by Color</th>
<th>Percent of Total Census</th>
<th>Estimated Production Numbers</th>
<th>Estimated Number Extant</th>
<th>Rarity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regency TR-1</td>
<td>All Colors</td>
<td>68</td>
<td>63%</td>
<td>105,000</td>
<td>5,000-10,000</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bone White</td>
<td>20</td>
<td>29%</td>
<td>31,000</td>
<td>1,500-3,000</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cloud Gray</td>
<td>15</td>
<td>22%</td>
<td>23,000</td>
<td>1,100-2,300</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mandarin Red</td>
<td>12</td>
<td>18%</td>
<td>19,000</td>
<td>950-1,900</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>11</td>
<td>16%</td>
<td>17,000</td>
<td>850-1,700</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forest Green</td>
<td>5</td>
<td>7%</td>
<td>8,000</td>
<td>400-800</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mahogany</td>
<td>3</td>
<td>4%</td>
<td>5,000</td>
<td>250-500</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pearlescent White</td>
<td>1</td>
<td>1%</td>
<td>200</td>
<td>15-30</td>
<td>R/VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pearlescent Blue</td>
<td>1</td>
<td>1%</td>
<td>200</td>
<td>15-30</td>
<td>R/VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pearlescent Pink</td>
<td>0</td>
<td>0%</td>
<td>200</td>
<td>15-30</td>
<td>R/VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pearlescent Lavender</td>
<td>0</td>
<td>0%</td>
<td>200</td>
<td>15-30</td>
<td>R/VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pearlescent Lime</td>
<td>0</td>
<td>0%</td>
<td>200</td>
<td>15-30</td>
<td>R/VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clear (back)</td>
<td>0</td>
<td>0%</td>
<td>100</td>
<td>10-25</td>
<td>VR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clear (front/back)</td>
<td>0</td>
<td>0%</td>
<td>25</td>
<td>5-20</td>
<td>VR</td>
<td></td>
</tr>
<tr>
<td>Reg. TR-1G</td>
<td>All Colors</td>
<td>20</td>
<td>19%</td>
<td>31,000</td>
<td>1,500-3,000</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>12</td>
<td>60%</td>
<td>19,000</td>
<td>1,000-2,000</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gray</td>
<td>3</td>
<td>15%</td>
<td>4,000</td>
<td>200-400</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coral</td>
<td>3</td>
<td>15%</td>
<td>4,000</td>
<td>200-400</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turquoise</td>
<td>2</td>
<td>10%</td>
<td>3,000</td>
<td>150-300</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yellow</td>
<td>0</td>
<td>0%</td>
<td>1,000</td>
<td>50-100</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Regency TR-4</td>
<td>All Colors</td>
<td>7</td>
<td>6%</td>
<td>11,000</td>
<td>550-1,100</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>5</td>
<td>71%</td>
<td>4,000</td>
<td>200-400</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>1</td>
<td>14%</td>
<td>4,000</td>
<td>200-400</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ivory</td>
<td>1</td>
<td>14%</td>
<td>3,000</td>
<td>150-300</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Bulova 250</td>
<td>All Colors</td>
<td>6</td>
<td>6%</td>
<td>9,000</td>
<td>450-900</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ivory</td>
<td>4</td>
<td>67%</td>
<td>6,000</td>
<td>300-600</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>1</td>
<td>17%</td>
<td>2,000</td>
<td>100-200</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown Leather</td>
<td>1</td>
<td>17%</td>
<td>1,000</td>
<td>50-100</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Mantola M-4D</td>
<td>All Colors</td>
<td>5</td>
<td>5%</td>
<td>8,000</td>
<td>400-800</td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>2</td>
<td>40%</td>
<td>3,000</td>
<td>150-300</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>2</td>
<td>40%</td>
<td>3,000</td>
<td>150-300</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ivory</td>
<td>1</td>
<td>20%</td>
<td>2,000</td>
<td>100-200</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Mitchell Series</td>
<td>All Colors</td>
<td>2</td>
<td>2%</td>
<td>3,000</td>
<td>150-300</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1101 Suntan</td>
<td>1</td>
<td>50%</td>
<td>2,000</td>
<td>100-200</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1102 Alligator</td>
<td>0</td>
<td>0%</td>
<td>500</td>
<td>25-50</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1103 Antique White</td>
<td>1</td>
<td>50%</td>
<td>500</td>
<td>25-50</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Entire Family</td>
<td>(30 variants)</td>
<td>108</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See Table 2 for explanation.
that no more than 105,000 complete radios were built and shipped. In any case, computations in the census table are based upon an estimated production/distribution figure of 105,000 TR-1 units.

I estimate that with the exception of the rare pearlescent and clear-cased TR-1s, which because of their distinctive appearance, would have been more likely to have been saved, the number of surviving examples for each variant is in the range of approximately five to ten percent of the original production. It is reasonable to assume that each of the variants in the family would be represented in the eBay census by an approximately uniform proportion of the number of its surviving examples (again, with the exception of the rare pearlescent and clear cased TR-1s).

Five to ten percent of the established 105,000 (approximate) production of Regency TR-1s gives the 5,000 – 10,000 estimated number of TR-1s extant. (Calculated estimates in this analysis are rounded to no more than two significant digits to avoid any inference of greater accuracy.) The number of TR-1s (68) encountered in the Family Census (Table 1), when divided by the median estimate of the number extant (7,500), yields the proportion (0.009 or 0.9 percent) of surviving examples appearing in the census. If the eleven-month census is normalized to one year, the percentage of TR-1s one would have expected to appear on eBay for a full year would be almost one percent of the extant examples. That one percent rate is probably a good representation of the average yearly count of TR-1s on eBay from its inception in 1995 through 2004. (There have been somewhat

<table>
<thead>
<tr>
<th>Rarity Descriptor</th>
<th>Abbreviation</th>
<th>Number of Extant Examples</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>UNK</td>
<td>0</td>
<td>May not exist</td>
</tr>
<tr>
<td>Unique</td>
<td>UNQ</td>
<td>1</td>
<td>Single documented example</td>
</tr>
<tr>
<td>Extremely Rare</td>
<td>XR</td>
<td>2-4</td>
<td>Uncollectable</td>
</tr>
<tr>
<td>Very Rare</td>
<td>VR</td>
<td>5-20</td>
<td>Highly competed</td>
</tr>
<tr>
<td>Rare</td>
<td>R</td>
<td>21-100</td>
<td>Very difficult to find</td>
</tr>
<tr>
<td>Scarce</td>
<td>S</td>
<td>101-500</td>
<td>Difficult to find</td>
</tr>
<tr>
<td>Uncommon</td>
<td>U</td>
<td>501-2,000</td>
<td>Infrequently seen</td>
</tr>
<tr>
<td>Common</td>
<td>C</td>
<td>2,001-10,000</td>
<td>Easily acquired</td>
</tr>
<tr>
<td>Abundant</td>
<td>A</td>
<td>Over 10,000</td>
<td>Prevalent in multiple venues</td>
</tr>
</tbody>
</table>

Table 2. Rarity Scale for Vintage Radios. Scale is for all examples extant in collector and non-collector hands.
more TR-1s appearing on eBay in recent years, but somewhat fewer in the earlier years.) So using the one-percent-per-year estimate, for the first nine-year period of eBay operations, there have probably been on the order of nine percent of all surviving examples of the TR-1 represented. This seems like a reasonable figure, lending credence to the assumption upon which it is based, i.e., that the number of surviving examples is between five and ten percent of production.

By applying the five to ten percent survival rate and the 0.009 TR-1 representation rate in the census to each model and each variant in the census, I derived the estimated production and extant numbers for each, as shown in Table 1. The smaller the number of variants counted for the census, the more approximate these results are likely to be. But all in all, they may be the best attempt to date to derive these numbers; and for the first time form an objective, systematized attempt to do so.

The rare pearlescents, clear-cased sets, and Mitchells are too infrequently encountered for their numbers extant to be accurately represented in a census of this size. Also, because the pearlescents and clear-cased sets were probably recognized as very special examples of the first transistor radio, I believe they would have been more highly valued by their owners and hence more likely to have survived to this day. Consequently, the number of extant examples is probably a higher percentage of their production than estimated for the other variants. Similarly, collectors and owners today, recognizing their higher monetary value, are probably more likely to offer them for sale on eBay than in other venues, given the prevailing perception (rightly or wrongly) that eBay offers the greatest probability of the highest price realized for great rarities and for objects for which value is difficult to accurately assess. So, as infrequently as the pearlescents, for instance, are encountered even on eBay, their numbers (just two) are probably over represented in the census. I have taken this into account in estimating the original production numbers and numbers of extant examples for the pearlescents and clear-cased variants. Even so, the estimates for the pearlescents, clear-cased sets, and Mitchells are more likely to be subject to revision as more data become available.

**Collecting Considerations - Rarity and Values**

The Regency TR-1 Family Census table is an attempt to establish concrete estimates of model, variant, and color rarity. Short of that goal, it can most reliably be used as a general guide to relative rarities of the TR-1 related variants. The numbers of extant examples can only
be estimated, and it is doubtful that authoritative production numbers will surface for the variants.

Table 2 is my attempt to define objectively, in terms of specific numbers of surviving sets, common descriptions of rarity used by collectors. The ranges of numbers extant (rarity classes) were chosen with the TR-1 family in mind, but they may be useful for other transistor radio categories and tube radios as well. In general, each class in the rarity hierarchy was set up to be approximately five times as broad as the next smaller one. This geometric progression of the scale is more useful than a simple, arithmetic one. In most fields of collecting, adjectival statements of rarity, not being well-defined, are unfortunately subjective and inconsistent.

The census results and their analysis support what observant collectors have known for some time: that the pearlescent TR-1s and several other variants are rare; that some of the other color variants are scarce; and interestingly, that the very first transistor radio itself, the Regency TR-1, is the most common of all of the related models that belong to the family, including the TR-1G and TR-4 models. The TR-1 appears to be more than three times as common as the TR-1G and nearly ten times as common as the TR-4. Rarity (supply), of course, is just one of the two common denominators of value. The other is demand. Strong collector demand for an example of the world’s first transistor radio has resulted in a significantly higher value for the Regency TR-1 relative to its scarcer closest relatives (the TR-1G and TR-4).

At the opposite end of the TR-1 family rarity scale, the pearlescent and clear-cased TR-1s are so seldom offered for sale, their values are very difficult to establish. Condition, sales venue, price precedence and momentum, competition, and collector personalities all come into play in the extreme when extreme rarities are offered for sale. As long as transistor radio collecting continues to be popular, each transaction involving one of these extreme rarities is likely to be a significant event with an unpredictable outcome.

Annotated Bibliography

Davis, Paul D. “The Breakthrough Breadboard,” in *Southwestern Historical Quarterly, Vol. 97, No. 1*, Jul, 1993, pp.56-80. (The most detailed description of the four-day Texas Instruments effort to design and build the first prototype breadboard in the TR-1 project, by a member of the TI development team. Also reprinted in *Transistor Network*, Vols. 24-29.)


**About the Author:**

Paul Farmer was born in Washington, D.C. in 1946. He earned a B.A. degree in Political Geography from the University of Maryland in 1968. He studied Wilderness Geography there during the 1970s and Fine Art Photography at Northern Virginia Community College in the 1980s. In 2001, he concluded a distinguished, 32-year career with the Central Intelligence Agency. He has been an active environmentalist throughout his adult life. He is a Director of the Rappahannock League for Environmental Protection. Paul has held amateur radio call
K3YFQ since 1963. He collects colorful plastic radios (tube and transistor) of the 1930s – 1950s, mint National communications receivers, a few early battery sets, mass-market tube audio equipment, and a wide range of rare and obscure radios. He enjoys the industrial design artistry of vintage American and Japanese equipment as much as any of the many aspects of radio history. He is a frequent contributor to *Radio Age*, the vintage radio journal of the Mid-Atlantic Antique Radio Club (MAARC), Vice President of MAARC, Life Member of AWA, and an appraiser of antique radios and related equipment.
Kodel's Founder, Clarence Ogden

Early in the wireless era Cincinnati, Ohio, became the home of several major receiver and radio equipment manufacturers. Among them, a small basement operation grew into the Kodel Radio Corporation. Although the company became a leader in technology, very little has been published concerning Kodel's roots and its founder, Clarence Ogden (Fig. 1). During the rapid growth of radio in the 1920s, Kodel produced a series of receivers and socket-power devices that ranked among the best in the industry. Clarence Ogden became one of Cincinnati's leading businessmen.

Ogden's electrical experimentation started at an early age. He possessed a sharp mechanical and electrical mind. His accomplishments gained the attention of fellow inventors who quickly learned to respect his work. Thomas Edison admired Ogden's contributions, and offered him a laboratory with unlimited resources to explore any field he desired. Edison later made the statement, “He has the most versatile mind I have ever encountered. He is able to work on experiments leading to two inventions with neither of them suffering” [1]. Ogden, or “C. E.” as he was later known, owned numerous patents and possessed a natural flair for business. His early life was not easy, but that life molded a man who learned at a very young age that perseverance was required if success was to be achieved.

Figure 1. Clarence Ogden, Kodel’s founder. (Ogden family collection.)
Clarence Edward Ogden was born on a small farm at Redbank, Ohio (Hamilton County) on August 29, 1890, and as a child, lived a poor country life. While performing the rigorous tasks of everyday life on the farm, he managed to attend elementary school. He realized quickly that to succeed, he would need to further his education. Although he had to walk several miles to catch a trolley and ride across town, he began further studies inside the city limits at Walnut Hills School. When officials learned that he actually lived outside the city, they imposed tuition of thirty dollars per year, forcing Ogden to quit.

During the next few years he continued to labor on the farm, doing anything he could to earn extra money. A turning point in his life came when his father sold the farm and moved to Cincinnati. Ogden decided to find work, and soon secured a position as an elevator operator in a shoe factory on Sycamore Street at a salary of three dollars per week. He enrolled in night classes at the Ohio Mechanics Institute to study physics and engineering. Soon after, his father became ill and he was forced to quit school to support the family. Eventually the situation improved and Ogden was able to continue his studies.

Life consisted of working in the elevator during the day studying books borrowed from the library and attending classes at night, leaving little time for anything else. In a newspaper interview written years later, Ogden commented that this was a point where fate played a hand [2]. One very cold December morning in 1910 he arrived at work and discovered that “the great Sycamore Street fire” had destroyed the majority of the shoe district, including the building where he worked [3]. Unfortunately, his books, papers and notes had been left behind in the elevator, and everything perished in the fire. At this point he could have abandoned his plans for a career, but a strong desire for a better future gave him the energy to press ahead, and he found a job managing a sales route for a typewriter company. He was not thrilled with the work, but knew that the sales experience would come in handy.

**Ogden Begins to Develop Battery Chargers**

He continued his studies in the fields of drafting, machine design, sales, advertising, and steam design. His interests focused on electrical
apparatus and the conversion of alternating current into direct current. He began designing battery charging apparatus based on a vibrating reed rectifier, and set up a small factory in the basement of his home to manufacture an improved battery charger. His first business was called the Ogden Manufacturing Company.

To supplement his meager earnings from battery charger sales, he continued to pursue employment. The Groh Company of Cincinnati offered him a job selling electric motors and supplies. Groh was an agency for Walker Electric Vehicles, and when company officials decided to open a branch agency in Cincinnati, they offered Ogden the position of district manager. He agreed to handle the agency and sell trucks on a commission basis.

One of the first problems he encountered was, ironically, the charging of batteries. The job was time consuming and required an attendant to monitor the elaborate and dangerous task. Ogden thought that if he could convince customers that the job of charging could be done automatically without the use of an attendant, vehicle sales would increase dramatically. He improved his charger designs and when satisfied, he presented them to several major manufacturers, who laughed and deemed them unnecessary.

The Automatic Electrical Devices Company is Formed

Ogden did not lose faith, continued manufacturing operations in his small shop, and further improved his designs. Every time he sold a truck, he sold one of his charging devices with it, and along with his success selling trucks he began receiving orders for the chargers. Business increased and he hired co-op students from the University of Cincinnati to help. On October 8, 1917, he filed with Ohio's Secretary of State for incorporation of the Automatic Electrical Devices Company [4]. Sales exceeded expectations, and the new company was forced to move to a larger space in a loft at 120 Opera Place. In two years the business had grown to the extent that he had to move to West Third Street. One reason for the rapid growth was the commissioning by the War Department of the development and manufacture of special rectifying equipment for the Army. At the end of the War, an award was presented to Automatic Electrical Devices Company for outstanding service [5].
Ogden's early designs were not limited to charging equipment. The trucks he sold seemed to have a design flaw in the electrical controlling device. The controller was made of wood, which had a tendency with age to crack, warp and eventually break, causing malfunctions and even fire. Ogden designed a new steel controller (Fig. 2), and once again offered the design to major companies who turned him down. He submitted the idea to the U.S. War Department, which apparently became convinced of its merit. Orders for government trucks at the beginning of World War I specified Ogden's controller design. One of the largest orders for the controller came in 1920 from Dr. Charles Steinmetz of the Steinmetz Electric Motor Car Company, who preferred the Ogden design to a General Electric design for use in his industrial trucks and delivery cars. (Steinmetz had earlier been the Chief Consulting Engineer at GE. In 1920 he established his electric car company in Brooklyn. Given Steinmetz's long-standing affiliation with GE, these orders represented a particularly sweet victory for Clarence Ogden.)

At the close of the War orders fell off sharply for both controllers and chargers, and Ogden knew that a new charger design for home use was necessary to secure the future of his company. He designed and built a new fully automatic car battery charger that he named “Homcharger,” which he marketed for use in the home garage. The Homcharger was cheap to buy and use, and allowed charging of batteries independent of a service station. At the time that the wall-mount Models A and W were introduced Ogden launched a successful advertising campaign.

Soon after, home radios appeared on the market and Ogden saw an opportunity to sell chargers for radio batteries. He designed and built the Model R portable, called the Radio Deluxe. Another massive advertising campaign was used to promote the device. Ads appeared in all of the popular radio magazines (Fig. 3). The company advertised that the charger could charge any A or B battery completely for five cents at a charging current of up to five amps.

Orders began pouring in almost immediately, production increased, and sales were so encouraging that by December 1922 branch offices were established for sales territories from New York to Los Angeles and Detroit to Dallas. The Automatic Electrical Devices Company had to expand its factory on West Third Street, and at that time the company claimed to be the largest manufacturer of vibrating reed rectifiers in the world [6]. Soon the Homcharger was advertised as “best by test,” with endorsements from the Radio Labs of the New...
Figure 2. This patent for Ogden's electrical controller was granted September 16, 1919. The controller was a highly successful product for Automatic Electrical Devices.
Figure 3. Homcharger ad from the August 1922 issue of Radio Broadcast. By this time, Automatic Electrical Devices was advertising in popular radio magazines and aggressively seeking sales for radio battery chargers.
Figure 4. Homcharger ad from the *Crosley Broadcaster*, early 1924. Note the “Gold Seal” emblem, and the statement, “Not Genuine Without the Gold Seal.”
York Evening Mail and the National Board of Fire Insurance Underwriters [7]. Competitors claimed their chargers were comparable to the Homcharger, prompting Automatic Electrical Devices to add the “Gold Seal” to their trademark (Fig. 4). Automatic Electrical Devices' ads warned against cheap imitations, and advised consumers to “look for and insist on the Gold Seal.” The Gold Seal Homcharger was widely advertised in publications such as the Crosley Radio Weekly [8].

**The Kodel Manufacturing Company is Formed**

Ogden was becoming a successful businessman, and given his success with radio battery chargers, it seemed only fitting that he should join the ranks of Cincinnati radio manufacturers. With help from his brother Perry, and many friends, including John Church (Fig. 5), who had been the founder and owner of Harmony Radio before becoming chief engineer for Ogden's new company, Ogden prepared to launch a new radio company [9]. By April 1924 Ogden's team had developed a suitable circuit and was ready to market their radio called the “Kodel.” It has been said that the name Kodel was derived from “Ko” for Kodak and “del” from Ogden's wife, Della. However, an Ogden family member clarified in an interview that the name was actually derived from a contraction of Clarence Ogden and Della Ogden. Initially it was to be “Codel,” but Ogden decided to change the C to a K, making it Kodel, and to name the new company the Kodel Manufacturing Company [10, 11]. The Kodel trademark was filed with the United States Patent Office May 27, 1924, and was accepted and published in the official Gazette on August 26, 1924.

The choice of name probably was intended to remind consumers of a camera, because Kodel

---

Figure 5. Kodel Chief Engineer John Church. (From the June 1928 Kodel Socket Power News.)
advertising described the portable Model P-11 as “The Camera of Radio.” This first Kodel radio was enclosed in a small leatherette case and somewhat resembled a Kodak camera (Fig. 6). A one-tube compact non-regenerative receiver, it used fifteen feet of aerial and ground wire and a compression type tuning capacitor. The P-11 made its debut in the *Cincinnati Enquirer* radio section on June 8, 1924. The article ran just one week after Crosley introduced its all-new 51P portable in a similar article. Testing was completed by the *Radio Digest Illustrated* Labs. A feature article on operating and troubleshooting the new set appeared on July 5, 1924. Statistics released by the company reported that production ranged from 800 to 2,000 sets per day by mid-July [12].

In October 1924 Kodel introduced an expanded line of radio sets. Advertising was targeted at those interested in quality at a low price. Kodel claimed to have a “radio for every purpose and any purse”. (Table 1 lists the Kodel sets offered during the years that Kodel made radios. There may be a few items not listed, for example, Kodel offered some of its sets in kit form around 1925.) The new line included the S-1 crystal set (Fig. 7), the original P-11 one-tube portable, the P-12 two-tube portable, the P-14 four-tube portable, the C-11 one-tube table model, the C-12 two-tube table model, the C-13 three-tube table model (which, incidentally, claimed to give 5-tube volume due to reflex amplification), and the C-14 four-tube table model (Fig. 8). Optional equipment included a battery cabinet that

![Figure 6. Kodel's first radio, the Model P-11, called "The Camera of Radio." (Left: from Kodel Bulletin Number K 539, 1924; right: a P-11 from the author's collection.)](image-url)
Table 1.
Kodel Radio Models, 1924-1926

<table>
<thead>
<tr>
<th>Model</th>
<th>Tubes</th>
<th>Description</th>
<th>Model Year</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-11</td>
<td>1</td>
<td>One dial</td>
<td>1924</td>
<td>$10</td>
</tr>
<tr>
<td>C-12</td>
<td>2</td>
<td>One dial</td>
<td>1924</td>
<td>$18</td>
</tr>
<tr>
<td>C-13</td>
<td>3</td>
<td>Reflexed</td>
<td>1924</td>
<td>$28</td>
</tr>
<tr>
<td>C-14</td>
<td>4</td>
<td>Two dials</td>
<td>1924</td>
<td>$32.50</td>
</tr>
<tr>
<td>C-111</td>
<td>1</td>
<td>One dial</td>
<td>1925</td>
<td>$12</td>
</tr>
<tr>
<td>C-112</td>
<td>2</td>
<td>One dial</td>
<td>1925</td>
<td>$20</td>
</tr>
<tr>
<td>C-113</td>
<td>3</td>
<td>Two dials</td>
<td>1925</td>
<td>$30 to $31.50</td>
</tr>
<tr>
<td>C-114</td>
<td>4</td>
<td>Two dials</td>
<td>1925</td>
<td>$36</td>
</tr>
<tr>
<td>Logodyne Big 5</td>
<td>5</td>
<td>Three dials</td>
<td>1925</td>
<td>$90</td>
</tr>
<tr>
<td>Logodyne Big 5 Console</td>
<td>5</td>
<td>Three dials, built-in speaker</td>
<td>1925</td>
<td>$275</td>
</tr>
<tr>
<td>Logodyne Std. 5</td>
<td>5</td>
<td>Three dials</td>
<td>1925</td>
<td>$70</td>
</tr>
<tr>
<td>Logodyne Std. 5 Console</td>
<td>5</td>
<td>Three dials, built-in speaker</td>
<td>1925</td>
<td>$165</td>
</tr>
<tr>
<td>P-11</td>
<td>1</td>
<td>Non-regenerative, portable</td>
<td>1924</td>
<td>$16 to $18.50</td>
</tr>
<tr>
<td>P-12 (Portable)</td>
<td>2</td>
<td>Portable</td>
<td>1924</td>
<td>$22.50</td>
</tr>
<tr>
<td>P-12 (Table model)</td>
<td>2</td>
<td>Table model</td>
<td>1924</td>
<td>$18</td>
</tr>
<tr>
<td>P-14</td>
<td>4</td>
<td>Portable</td>
<td>1924</td>
<td>$37.50</td>
</tr>
<tr>
<td>S-1</td>
<td>Xtal</td>
<td>Crystal set</td>
<td>1924</td>
<td>$5 to $6</td>
</tr>
<tr>
<td>Logodyne Unitrola</td>
<td>5</td>
<td>For phonograph adaption</td>
<td>1925</td>
<td>$87.50</td>
</tr>
<tr>
<td>Unitrol Std. 5</td>
<td>5</td>
<td>One dial plus verniers</td>
<td>1926</td>
<td>$85</td>
</tr>
<tr>
<td>Unitrol Big 6</td>
<td>6</td>
<td>One dial plus verniers</td>
<td>1926</td>
<td>$115</td>
</tr>
</tbody>
</table>
Figure 7. Model S-1 crystal set, which sold for $5, later $6. (From Kodel Bulletin K 539, 1924.)

Figure 8. The Kodel C-14, a four-tube table model. It sold for $32.50 in 1924. (Author’s collection.)
could be used with all sets, but fit perfectly under the C-14 as a
matched set.

The original models were all encased in thin wood cabinets covered
with black leatherette. Engineering specifications identified the
materials used in construction to be of the highest caliber. Panels
were made of Formica, purchased directly from the Formica plant in
Cincinnati. Knobs, tube sockets, and rheostats were molded from
Bakelite, and all carried the Kodel trademark and a part number.
Audio transformers were wound around a core of laminated silicon
steel with number 44 wire; their tops sported a plate with the Kodel
name and the slogan “Compare the Quality.” Radio frequency
transformers were wound with green silk wire around a Formica core.
Kodel Engineers claimed that their variable capacitors were the
simplest and most efficient low-loss capacitors on the market [13].

The advertising department was careful to advise that the new
Kodel Manufacturing Company was under the same management that
made the “Homcharger” famous. The Homcharger continued to be
manufactured by the Automatic Electrical Devices Company until
January 1925, when both companies merged and the name was
changed to Kodel Radio Corporation. At the time of incorporation,
the merged company was reportedly worth $2 million and was
claimed to be the second largest manufacturer of medium priced
receivers in the world [14].

Kodel Expands Its Radio Line

Clarence Ogden predicted that 1925 would be the radio industry's
greatest year, and 1925 was, without a doubt, the most active year to
date at Kodel [15]. He also noted that surveys done by the Kodel staff
indicated that the public was interested in better class merchandise
and a wide selection of programs that fans could choose from through
the use of a good tube set. During the first quarter Kodel reported that
they had produced and sold (cumulatively) over 50,000 radio sets.
Production schedules increased to 24 hours per day and several new
models were introduced (Figs. 9 through 11). The C-13 and C-14
were carried over into the new season, enclosed in solid mahogany
cases, and designated the C-113 and C-114 models. In addition, two
new amplifiers were offered, a one-tube (Model A-11), and a two-
tube (Model A-12). Kodel Chief Engineer John Church and Engineer
Perry Ogden were busy completing plans for the release of an all new
5-tube set, scheduled for release just in time for Cincinnati’s “First
Annual Radio Exposition,” to be held in Cincinnati’s Music Hall during the week of March 9th. On March 8, the Cincinnati Enquirer published a special “Radio Show Number” and among the latest Fada Neutrodynes, Radiola superheterodynes, and Crosley Trirdynes, came the Kodel Radio Corporation’s announcement introducing the “Logodyne” [16].

The Logodyne Big Five was introduced initially in an advertisement that proclaimed the set to be “radio's most beautiful and efficient receiver.” The circuit, developed by John Church, had two stages of tuned radio frequency amplification, the “famous” Kodel detector circuit, and two stages of audio amplification. The black Formica sub-panel was fully engraved with unique gold scrollwork by the Veri-Chrome Lab process [17]. (Veri-Chrome was a Cincinnati firm, and about this time, Formica bought a controlling interest in Veri-Chrome Laboratories.) The cabinet was mahogany, finished in brown tone with a satin
finish. A companion article declared that the Kodel Company was interested in seeing Cincinnati become as prominent in radio development as Detroit had become in the auto industry [18]. One month later Kodel released a smaller version of the Big Five - the “Standard Five” (Fig. 12). The front panel and sub-panels were smaller, and one filament rheostat was eliminated.

Radio Station WKRC is Established

In addition to the introduction of the new models noted above, Cincinnati headlines were made again on March 18, with the announcement that Kodel had purchased radio station WMH from the Ainsworth Gates Radio Company. Rumors of the possible sale had been circulating among the broadcasting community for several weeks before the Cincinnati Enquirer reported that the newspaper had contacted the radio supervisor of the Eighth District to confirm the sale. Transfer to the new owner was immediate, and Clarence Ogden reported that he would make changes in equipment that would include the purchase of additional apparatus from Western Electric. Upon takeover WMH's call letters would be changed; an application was being submitted to seek the call WKRC (for Kodel Radio Corporation). The studios were to remain in the new Alms Hotel (Fig. 13) and would be completely renovated and enlarged during the summer months. The purchase price was not discussed, but the Enquirer released a figure of $50,000. Ogden told the public that expectations for the station would place it among the most prominent

![Figure 12. The Standard Five. It sold for $70 in 1925. (Author's collection.)](image)
in the nation with equipment and power to provide “coast to coast range”. He also noted “as radio manufacturers and manufacturers of battery chargers, we felt it a duty to provide entertainment and diversion to the people who buy radio equipment” [19]. Ogden’s feelings regarding the connection between broadcasting and equipment manufacturing were later incorporated into a sales slogan printed on company correspondence. The slogan, copyrighted in 1926, read “Help support radio broadcasting by using the products of those who entertain you.”

Leo Ainsworth of Ainsworth Gates reported that he needed to sell WMH so that he could devote his time solely to the manufacture of radio receivers. This, of course, was short lived due to his untimely
and tragic death just one year later [20].

On March 20 Kodel hosted a dinner at the Hotel Havlin to officially introduce WKRC to the public. Clarence Ogden took the opportunity to reiterate his opinion regarding Cincinnati's prominence in radio manufacturing, and paid tribute to the Crosley Corporation and the other men of radio in the community. He introduced Kodel's Patent Attorney and Company Secretary Arthur Ewald (Fig. 14), Chief Engineer John Church, Publicity Manager J. L. Koons, and new Station Manager and Studio Director Eugene Mittendorf. Mittendorf reported that WMH would officially close March 27 and WKRC would open April 6 [21].

During the festivities, the audience was introduced to Della Ogden who recited a poem that she authored to celebrate the naming of WKRC. (Della's name had been used along with her husband's name to formulate the company name, Kodel. Her name and Clarence's name were also combined in naming their elegant Cincinnati mansion on East McMillan Street, Villa Delclar, pictured in Figure 15. The home is still there today.)

On April 6, shortly after 8 p.m., Clarence Ogden took the microphone and advised his new audience that WKRC would remain “one big link between

---

Figure 14. Arthur Ewald, Kodel's patent attorney and company secretary. (From Kodel Socket Power News, August 1928.)

Figure 15. Villa Delclar, Clarence and Della Ogden’s splendid home on East McMillan Street in Cincinnati. (Author's photograph.)
the radio public and ourselves.” Following speeches by Paul Greene, Director at WSAI; Fred Smith, Director at WLW; and John F. Bichl, Vice President of Kodel; the entertainment program began.

The purchase of WMH and the associated renovation of the Alms studios was one of many projects in process at Kodel early in 1925. Homcharger production was increased dramatically due to an agreement to manufacture chargers for Sears Roebuck. Sears purchased the units from Kodel and branded them “The WLS Rectifier.” (WLS stood for “World’s Largest Store,” a Sears motto.) The nameplate stated that the units were manufactured for Sears, but did not carry the Kodel mark.

Production of receivers and plans for additional models made it inevitable that additional factory floor space or a new headquarters would be required. A site was chosen in the basin area of downtown Cincinnati on Pearl Street, and renovation and expansion began immediately. A meeting of Kodel executives and far-flung distributors took place in Cincinnati on July 5, 1925 to show off the new plant (Fig. 16). Production began there on July 6th [22]. The building was

Figure 16. Kodel’s Pearl Street factory prior to the September 1927 expansion. (From Socket Power News, May 15, 1927.)
six stories high with three one-story wings. Shipping and receiving was accommodated by the installation of a rail spur from the local yard. The roof of the building had an antenna system similar to those at WKRC. The front of the building had a crest at the top center with the new “KRC” logo, which also began to appear on all of the receiving sets manufactured at the Pearl Street factory [23]. Figures 17 and 18 show interior shots of the production facilities.

The 1925 Radio Models

Kodel released two new console models for the season. The first, based on the Logodyne Big 5, had a massive four leg cabinet with two doors and a center fold down desk panel that opened to reveal the controls. The right door covered the built-in speaker, the left opened to reveal the batteries and charger. The Standard Five console was of the same general design as the Big Five, only on a slightly smaller scale, with no center drop down panel. The Big Five console sold for $275 (Fig 19) and the Standard Five for $165. These two models were

Figure 17. Homcharger assembly area of the Kodel plant. (From a 1926 Kodel brochure.)
Figure 18. Testing area of the Kodel factory. (From a 1926 Kodel brochure.)

Figure 19. Logodyne Big Five console. With a list price of $275, this was one of Kodel’s most expensive radios. (From Radio Retailing, September 1925.)
also available in panel-assembled kit form. The Standard Five was used as the base set for the new “Unitrola” Model, designed as a replacement unit for the phonograph motor board in console and table phonographs. The motor board was removed and the Unitrola bolted in place. The Kodel reproducer unit mounted to the phonograph horn, turning the phonograph into a radio [24].

Another change in the 1925 season was that the “Gold Seal” name began to be applied to Kodel's crystal set and small tube sets still in production. That year Kodel offered one horn speaker model [25] the “Deluxe Amplifier” (Fig. 20) and also sold a solid mahogany cabinet style “amplifier” (Fig. 21) that incorporated a special tone chamber.

Table 2.
Kodel Amplifiers, Speakers, and Accessories.

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-11</td>
<td>One-tube amplifier</td>
<td>$12</td>
</tr>
<tr>
<td>A-12</td>
<td>Two-tube amplifier</td>
<td>$17</td>
</tr>
<tr>
<td>Filtometer</td>
<td>Wave trap</td>
<td>$10</td>
</tr>
<tr>
<td>Cone speaker</td>
<td>Speaker</td>
<td>$20</td>
</tr>
<tr>
<td>“Cabinet type amplifier”</td>
<td>Speaker</td>
<td>$27.50</td>
</tr>
<tr>
<td>“Deluxe amplifier”</td>
<td>Speaker</td>
<td>$25</td>
</tr>
<tr>
<td>Microphone loudspeaker</td>
<td>Speaker (Available with either the Kodel Jr.</td>
<td>$15 to $20</td>
</tr>
<tr>
<td></td>
<td>reproducer or the standard reproducer.)</td>
<td></td>
</tr>
<tr>
<td>Microphone loudspeaker &amp; lamp</td>
<td>Speaker and lamp</td>
<td>$26</td>
</tr>
<tr>
<td>Microphone lamp</td>
<td>Lamp</td>
<td>$9.75</td>
</tr>
</tbody>
</table>
Table 2 lists speakers and other radio accessories, such as a wave trap (Fig. 22) sold by Kodel. Kodel briefly offered a cone speaker, too (Fig. 23). (Figs. 20 through 24 are all taken from Kodel brochures of the era.) Possibly the best-known release for 1925 was the microphone loudspeaker model incorporating the Kodel reproducing unit in a replica of a microphone commonly used at broadcasting stations of the era (Fig. 24). Two nearly identical models were released. The $15 model housed the Kodel Jr. reproducer, the $20 model employed the standard reproducer [25].

The Kodel advertising department introduced the new line-up in a bi-weekly series of two-page ads that began running in Liberty magazine. The layouts included the new KRC logo, the statement of ownership for WKRC that included a drawing of the towers, and a slogan “KRC — The Emblem of Worth in Radio.” The slogan also began to appear on the dials of voltmeters used in Homcharger
production. The ads prompted the public to send for a free 16-page booklet titled, “The Secret To Distance and Volume In Radio” [26].

**Kodel's Emphasis Shifts to Socket Power**

If Clarence Ogden had any obsessions in life, there has never been any doubt that one was his search for the ultimate rectifier. 1926 was a year of transition for Kodel. The manufacture of radio sets was becoming overshadowed by Ogden's desire to become industry's leading manufacturer of direct current power devices. Kodel, of course, was already a leading manufacturer of quality home battery charging equipment. A major design problem for the radio industry had been the lack of affordable automatic power (battery eliminators), and many companies were working on the problem. The Homcharger did not lend itself to serving as a battery eliminator for radios because the vibrating reed created too much radio frequency noise to filter out.

Batteries were expensive, bulky and messy, and required frequent charging or replacement. By the mid-1920s, a rapidly increasing number of American homes were being wired with AC power, research on AC filament tubes was coming to fruition, and industry experts were predicting that before long, battery powered radios would be replaced by AC operated sets in urban areas. Even those families that had purchased battery sets earlier would likely have an interest in buying reasonably priced and reliable “socket-power” battery eliminators that could convert AC power to operate a radio.

Ogden's internal engineering staff, in conjunction with the engineering staff at the University of Cincinnati, selected a typical of
the era design using transformers, filter capacitors and a Tungar bulb for Kodel's first socket power unit released in 1926 [27]. By March an A unit, a B unit, and a combination A/B unit were available. (Fig. 25 shows a Kodel A supply Model 10.) The combination unit furnished 2-, 4-, or 6-volt filament voltages, plus plate voltages from 22½ to 150 volts. The units were housed in very heavy stamped metal cases with attractively plated hardware. These initial products sold well, but Ogden was working on a new rectifier, and on April 18, 1926 a news release introduced his latest discovery, called “Silite” [28].

The news release stated that Ogden and his staff had spent more than three years searching for an elusive element capable of “perfect” electrolytic rectification. Their discovery was a compound of silicon and metallic alloys. Common battery acid had been proven over the years to be the only cost effective known electrolyte that performed well over time. The problem with acid electrolytes was that the electrodes generally deteriorated with use. Since glass was generally found to be indestructible when exposed to acid, Ogden opted for a silicon-based material and found it to work well. The use of Silite in electrodes therefore opened the door to what Ogden and his staff claimed to be the “perfect” rectifier. The patent application for Ogden's electrolytic rectifier design was filed on August 6, 1926, and the resulting patent (number 1,661,703) appeared in the March 1928 *Gazette*.

Silite was immediately adapted to the Homcharger and to an all-new trickle charger unit. The trickle charger made a complete power unit when connected to a battery and used in conjunction with the receiver. It provided for silent non-distorted reception and kept the battery

![Figure 25. Kodel A supply Model 10 employing a Tungar bulb rectifier and an internal 6-volt battery for capacity. A socket was provided for plugging in a B-eliminator. (Author’s collection.)](image)
at peak performance. For larger receivers the upgraded Homcharger (employing the Silite-based rectification system) was used. Both chargers remained permanently connected. To further enhance charging with the new equipment, Kodel introduced a small device called the “Chargometer,” designed to disconnect the charging device automatically when the battery became fully charged [29].

Throughout 1926 Kodel continued to perfect and sell A-B-C units. The old standby non-Silite Homcharger received two major upgrades and the new name “Triple Duty Homcharger.” The upgrades included the addition of a rejuvenation circuit for radio tubes and a new eight-volt tap to supply voltage to new eight-volt AC tubes. The price remained the same at $19.50 [30].

Radio production remained at a steady pace during the first half of 1926, and Kodel released two new receivers featuring single control tuning. Tuning was accomplished via synchronization of all three capacitors, driven off the center capacitor. The outer two capacitors retained a vernier adjustment for fine tuning. The upgraded Standard Five Model received a new name, “The Kodel Unitrol Standard Five.” The “Kodel Big Six Unitrol” (Fig. 26) was an all-new receiver that employed six tubes. Both sets appeared in Radio Dealer for July

![Figure 26. The Big Six Unitrol receiver. (From a 1926 Kodel brochure.)](image)
1926, and appear to have been the last of the radio models designed and introduced by Kodel. That year the company introduced a new version of the reproduction microphone speaker that doubled as a speaker and lamp. The Kodel Radio Lamp sold for $26 with the speaker unit installed, and as a lamp only for $9.75 [31].

Radio Production Ceases; Kodel Focuses on Kuprox

During the last few months of 1926 Kodel's management assessed the future of radio production. A decision was made to abandon radio, and in February 1927, Kodel switched production solely to eliminators and chargers [32].

Kodel's engineers were busy experimenting with a secret new material known as “Kuprox,” developed by S. M. Allen of the Liebel Flarsheim Company in Cincinnati. The new material proved to be what Kodel later stated was a “miraculous new discovery” in rectification. Negotiations began immediately for Kodel to purchase exclusive rights for production of the new material. An office suite was converted into a makeshift lab and special furnaces were installed. The new material was a small copper oxide disk.

Ogden explained in simple terms that “through intense heat, generally known to vaporize and become steam, the particles in the copper were condensed, and within a magnetic field they are rearranged to form a new atomic structure that allows current to pass in only one direction.” The process was kept secret and guards admitted only those closely related to the research [33]. When the new product was announced to the public, Kodel began producing a company newspaper titled Socket Power News. Volume 1 appeared May 15, 1927, filled with news concerning Kuprox. The advertising department immediately produced a new booklet titled “A New Source of Radio Profit.” Power units and Homchargers could be retrofitted with the new rectifier (Fig. 27), eliminating Silite, reeds, and bulbs [34].

By mid-July 1927 the Kodel factory was so busy with production of Kuprox and Kuprox-controlled devices, that three eight-hour shifts were required. Demand was so high that Kodel's management envisioned the need for faster distribution. Bertram Smith, Manager of West Coast Operations, had been dabbling in pioneer aviation, and Perry Ogden was splitting his time between Kodel and engineering
interests at International Aircraft in Long Beach, California. The men quickly concluded that the needs of the business could be more effectively addressed with the use of air shipments, and Clarence Ogden was intrigued as usual (Fig. 28). The benefits of air transport were actually demonstrated by one of Kodel’s distributors in late July. General Sales Company of Detroit made an emergency shipment of Kuprox products to the Herpolsheimer Company of Grand Rapids via air to avert an emergency. This marked the beginning of air shipments when required to support Kodel distributors [35].

With business booming, in September 1927 Kodel was forced to expand its production facilities. The company acquired a seven-story building adjoining the existing factory. Within 36 hours of the purchase, walls were being opened and walkways were being installed. The new property included an additional rail spur that would prove helpful for expedited shipments. Kodel now claimed to be the

---

**Figure 27.** Left: Kodel “Multi-rate” rectifier. Right: Kuprox retrofit Model 10, which could be used in earlier reed or bulb type chargers and eliminators. (Author’s collection.)
The largest single factory unit in the county devoted solely to the production of radio power devices [36]. Table 3 lists Kodel's Kuprox battery eliminators offered in 1927. Fig. 29 shows a Model 161.

Also in September, Kodel claimed yet another major breakthrough in B-unit power, when engineers released an all-new hermetically sealed capacitor unit.

**Figure 28.** Quick to embrace new technology, Ogden was fascinated by airplanes as well as radios. Here Ogden (left) and Pacific Coast Kodel Representative, Bertram Smith, prepare to leave for the June 1928 Chicago Radio Show. Few firms used air shipments during the 1920s, but Kodel did! (From *Socket Power News*, June 1928.)

**Figure 29.** A Kodel Model 161 B supply (1927). It sold for $26.50. (Author’s collection.)
Table 3.
1927 Kuprox-based Battery Eliminator Models. (From “A New Source of Radio Profit,” a 1927 Kodel dealer brochure.)

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>A Voltage/Current</th>
<th>B Voltage/Current</th>
<th>C Voltage (Volts)</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>B only</td>
<td>45, 90 V @ 20 mA</td>
<td>45, 90, 180 V @ 35 mA</td>
<td></td>
<td>$14.50</td>
</tr>
<tr>
<td>106</td>
<td>A, B</td>
<td>6 V @ 2 A</td>
<td>45, 90, 180 V</td>
<td></td>
<td>$58.50</td>
</tr>
<tr>
<td>107</td>
<td>A, B, C</td>
<td>6 V @ 3 A</td>
<td>45, 70, 90, 150, 180 V</td>
<td>4, 10, 22.5, 40</td>
<td>$97.50</td>
</tr>
<tr>
<td>108</td>
<td>A, B, C</td>
<td>4 V @ 1 A</td>
<td>45, 90, 135 V</td>
<td>4, 22.5</td>
<td>$57.50</td>
</tr>
<tr>
<td>110</td>
<td>B only</td>
<td>45, 90, 150, 180 V @ 45 mA</td>
<td></td>
<td></td>
<td>$39.50</td>
</tr>
<tr>
<td>111</td>
<td>A, B</td>
<td>6 V @ 3 A</td>
<td>45, 90, 150, 180 V</td>
<td></td>
<td>$80</td>
</tr>
<tr>
<td>114</td>
<td>B, C</td>
<td>45, 90, 145 V @ 40 mA</td>
<td></td>
<td>4, 22.5</td>
<td>$37.50</td>
</tr>
<tr>
<td>116</td>
<td>B, C</td>
<td>45, 70, 90, 150, 180 V @ 100 mA</td>
<td></td>
<td>4, 10, 22.5, 40</td>
<td>$54.50</td>
</tr>
<tr>
<td>120</td>
<td>Power Amp &amp; B</td>
<td>45, 90, 180 V @ 35 mA</td>
<td></td>
<td></td>
<td>$45</td>
</tr>
<tr>
<td>161</td>
<td>B only</td>
<td>45, 90, 180 V @ 35 mA</td>
<td></td>
<td></td>
<td>$26.50</td>
</tr>
<tr>
<td>163</td>
<td>DC</td>
<td>45, 90, 120 V</td>
<td></td>
<td></td>
<td>$22.50</td>
</tr>
</tbody>
</table>
designed to last “virtually forever.” Engineers had known for years that a major problem in socket power units was the breakdown of capacitor blocks due to moisture seeping into the dielectric. It was said that the new capacitor blocks could be totally submerged in water without failure, and Kodel touted its being the exclusive producer of the new design [37].

Financially, 1927 was one of the best years at Kodel. Radio production had ceased and battery eliminator and other power device production was the company's money maker. Kodel published an interesting cartoon in Socket Power News, depicting a Kuprox man sitting on a pile of money while Santa Claus wished everyone a “Merry Kuprox and Prosperous New Year” (Fig. 30). Clarence Ogden ended the year on a high note when he announced that he and several interested parities would join forces to acquire the International Aircraft Corporation of Long Beach, California, and move it and its workforce to Cincinnati. Perry Ogden would oversee the move and Arthur Ewald was named president of the new venture. Clarence Ogden located property at Ancor, Ohio, and converted an old nitrate plant into factory and hanger space.

**Litigation Plagues Kodel**

The good cheer lasted only two weeks. On January 12, 1928, the beginning of a long court battle concerning the right to manufacture Kuprox began. During 1927 interested parties associated with the Union Switch and Signal Company had been dogging Kodel to allow them to use the Kuprox process. Kodel had rejected the proposals. Through what Ogden termed “Sour Grapes,” [38] the Union Switch and Signal Company, in partnership with Westinghouse Electric, filed suit against Kodel, alleging that Kodel had infringed on a patent filed by Lars O. Grondahl. Claiming that Grondahl had actually patented the process used to produce Kuprox in 1922, Union Switch stated that on June 7, 1925, Grondahl assigned the application and invention to them, followed on August 22, 1927, by assignment of the patent.

The Court was asked to issue a temporary restraining order, later to be made permanent. Union Switch also asked for an accounting of all profits by Kodel and damages [39]. While attorneys scrambled to research and document proof to substantiate the claim of absolute control of the patents, the advertising department continued to push the new products that Kodel offered. Although Socket Power News made no mention of the suit, several subtle articles appeared assuring
nervous Kodel dealers that Kuprox was owned and controlled by Kodel.

In April 1928 Kodel executives met and made a decision to further protect the company's interests in Kuprox by negotiating a deal with the Liebel Flasheim Company to buy all of the rights and patents.
Kodel paid $250,000, and Ogden made the claim that it was necessary to obtain immediate control because of the widespread interest by industrial organizations and public utilities [40]. The move was no doubt made to assure dealers that Kodel had every intention of maintaining control over Kuprox.

Unfortunately, the court did not agree, and Kodel lost the infringement suit on several claims. The Court granted an injunction to the plaintiffs, and ordered an accounting of all profits. Kodel's lawyers immediately filed an appeal, and Kodel continued to build and sell Kuprox rectification equipment. Brisk sales continued, and Kodel claimed that this was in part due to public apprehension concerning problems associated with the new AC sets. An article in *Socket Power News* claimed that in 1928 there were eight million battery sets still in operation, and the public demand for good, reliable power packs was at an all-time high [41]. Fig. 31 shows a Model 302 A supply.

In May 1928 Kodel announced that the company name would be changed from the Kodel Radio Corporation to The Kodel Electric and
Manufacturing Corporation. The name change was filed with the Secretary of State on May 11, and Ogden advised the public that the change was necessary to more accurately describe the company's current business thrusts [42].

Sales were steady in 1928, but by the first half of 1929, consumers were seeking new self-contained simple-to-use AC-powered radios with improved designs, and more manufacturers were offering such sets. Prospects for sales growth of separate battery eliminators were increasingly grim. Kodel began to decline financially, and Ogden and his staff knew that research and development for new products would be required if the company were to survive. In 1929 Ogden and his partners sold the International Aircraft Company to the Crosley Motor Car Company. Apparently Perry Ogden broke his ties with Kodel and his brother, and moved to the West Coast. It should be noted that the sale of International to Crosley coincides with Crosley’s acquisition of 193 acres of property at Sharonville, Ohio, for a private airport. Clarence Ogden also made the decision to sell his beloved radio station, WKRC, to John S. Boyd, owner and operator of WIBO in Chicago [43].

**New Products for Kodel: Clocks and Home Movie Equipment**

In May 1929 Kodel announced an all-new line of electric clocks (Fig. 32). The trademark used was “Kenmore” (not related to the Sears Kenmore brand). The clocks contained a synchronous frequency motor designed by Ogden. In all, more than twenty models for home use were developed and sold [44]. Kodel also produced and marketed a line of large advertising clocks for various clients, including Proctor and Gamble. By October 1929 the company was offering a new system of home movie equipment, dubbed “Homovie” (Fig. 33). The company claimed that the camera and movie projector would be the fastest selling item offered to radio dealers since the crystal set days [45].

Despite the creativity and new products offered by Kodel, the company lost money in 1929, 1930, and 1931, forcing the firm into receivership by October 1931. The final blow came December 31, 1931 when the district court heard the case concerning Kuprox and found in favor of the Plaintiff [46]. Kodel disappeared from Cincinnati's city directories in 1933, and the corporation was disbanded on November 14, 1934 [47]. Interestingly, Clarence Ogden
immediately resurrected the old Automatic Electrical Devices Company and filed for re-incorporation on October 3, 1934 [48].

During the next ten years Ogden's research and development was devoted to the “Homozone,” a machine designed to eliminate and destroy odors while purifying air. This new product was introduced to the public on November 29, 1939, and machines were sold all over the world [49]. During World War II a shortage of dry cell batteries prompted the design and production of a rechargeable flashlight battery. At the time of Ogden's death, work was underway in the Dominican Republic to develop a treatment for leprosy that would be more comfortable for patients. It involved bubbling oxygen through Chaulmoogra oil. Ogden's research interests were remarkably varied!

After the sale of International Aircraft, Ogden converted the property at Ancor and opened the Ogden Chemical Company, which
was best known for production of cleaning solutions. He was an avid yachtsman on the Ohio River and owned and operated a 37-foot cruiser named Del-clar (Fig. 34), but his true love in life was tinkering and inventing.

Clarence Ogden died at age 53 in March 1944 [50]. The Automatic Electrical Devices Company continued to operate and produce home charging devices and Hom ozone products until 1950 when it disappeared from the Cincinnati City Directory [51]. At that time, sales manager Nick Trikilis formed his own company, called Electro Products and Engineering Company. He secured all of the rights to Hom ozone products, including that trademark, and he moved his organization to Canton, Ohio. The business became the ARANAIR Corporation, and is in business today manufacturing electronic air purification equipment.

Figure 33. Kodel ad for home movie products, directed at dealers. (From Socket Power News, October 1929.)
Selected Biographies

John F. Church: Kodel's Chief Engineer from 1924 through 1930 was born in Cincinnati in 1898 and grew up in the suburbs of Norwood and Avondale. He graduated early from Hughes High School and attended the Virginia Military Institute where he graduated as an electrical engineer. He entered the Marine Air Corps and was responsible for setting a world altitude record in an open cockpit bi-wing plane. After his military service he became the youngest professor of mathematics at the Massachusetts Institute of Technology. In the early 1920s he returned to Cincinnati and organized the Harmony Radio Company. In 1924 Harmony went out of business and Church joined Kodel as Chief Engineer. He perfected several radio circuits and was solely responsible for development and design of the Logodyne receivers. When Kodel acquired station WMH, he was named Chief Engineer of the station, and was put in charge of the major renovations and upgrades that brought WKRC into existence. In 1930 he left Kodel and relocated in Chicago where he ran the Church and Anderson Company. In 1949 he returned to Cincinnati and became Executive Vice President of the Cincinnati Cordage Company, a company founded by his father. In 1975 he retired and moved to Ft. Lauderdale, Florida, where he died on February 19, 1979 [52].

Figure 34. Clarence Odgen's yacht, the Delclar. (Ogden family collection.)
Arthur H. Ewald: Also born in Cincinnati, Ewald was Secretary, Treasurer, and Legal Advisor for Automatic Electrical Devices and Kodel. He studied radio theory at an early age and then law before becoming an attorney and joining Automatic Electrical Devices. He is listed as the corporate attorney on the original incorporation papers. Ewald became an expert patent attorney and was responsible for filing for the major portion of the company's patents and trademarks. He served as president of the International Aircraft Corporation until its sale, and after the demise of Kodel, he practiced law and became president of the Sun Mutual Fire Insurance Company. In addition, he served as director and legal advisor for Apollo Savings and Loan, and was director of Eagle Savings and Loan. Ewald left on an extended vacation in France on June 23, 1952, and died there July 10 [54].

Perry V. Ogden: Born in Cincinnati, Perry Ogden (brother of Kodel owner Clarence Ogden) was an engineer at Kodel as well as Chief Engineer at International Aircraft Corporation. He worked closely with John Church at Kodel and frequently traveled to the West Coast to attend to duties at International Aircraft. Perry Ogden was instrumental in the relocation of International to the Ancor, Ohio, site. In 1929 International Aircraft was sold to the Crosley Motor Car Company. Ogden then relocated to California and began work at Boeing as a production chief until 1934 when he became a general superintendent. He eventually became a Boeing factory manager in Seattle. During World War II he was directly involved in the production of transports and twin engine bombers, including the Flying Fortress. He lived at Upland, California, and died in 1996 at age 92 [53].

References


2. Kerry Gale, “Fate Played a Hand in My Life,” Cincinnati Times Star, Radio Section, 7 March 1925, p. 5.

4. “Articles of Incorporation,” Charter Number 41,470, Ohio Department of the Secretary Of State.


9. “In The Enquirer Laboratory,” *Cincinnati Enquirer*, Radio Magazine Section, 3 May 1925, p. 3. (Short Biography of John F. Church.)


12. Ibid.


14. “Articles of Incorporation,” Charter Number 114,857, Ohio Department of the Secretary of State.

15. “Greatest Year,” *Cincinnati Enquirer*, 30 August, 1925.


25. *QST*, Vol. IX, No. 11, Nov. 1925, p. 100. (Kodel microphone speaker.)


37. Ibid, p. 11.
41. Ibid, p. 10.
47. “Articles Of Incorporation,” Charter Cancellation Certificate, 15 November 1934, Ohio Department of the Secretary of State.
51. “Articles of Dissolution,” 20 July 1950, Ohio Department of the Secretary of State.
53. “Obituary – Perry Ogden,” Email received 31 January 2002, from Ogden family, with details of his death in Upland, California.


Clarence Ogden's Patents, 1919-1928

1919 – 1316320 – Electric controller
       1316321 – Method of constructing resistance grids

1920 – 1327682 – Switchboard for charging storage batteries
       1344812 – Means for charging storage batteries

1922 – 1410073 – Electric controller
       1430106 – Means for charging storage batteries
       1430107 – Means for charging storage batteries

1923 – 1448147 – Electric controller

1924 – 1492309 – Switchboard

1927 – 1633224 – Storage battery

1928 - 1693421 – Vibrator for alternating current rectifiers
       1661703 – Electrolytic rectifier

Acknowledgment:

I am grateful to Charles Stinger for allowing me to use what may be the only known copies of Socket Power News; to George Freeman for his encouragement and support, and to my wife and son for their support and understanding.

About the Author:

John E. Leming, Jr., a native of Northern Kentucky, is a 1979 graduate of Eastern Kentucky University. John has a Bachelor of Science degree in industrial education and technology, and taught industrial arts in Kentucky and New Mexico. In 1984 he joined the
staff at General Electric's Aircraft Engine Group in Cincinnati as a configuration management specialist. In 1993 he went to work for the Ford Motor Company's Powertrain Operations in Sharonville, Ohio as a material control analyst.

John began researching and writing local historical articles in 1993, and has been frequently published in *Northern Kentucky Heritage* and *Kentucky Explorer* magazines. John held the position of history columnist for the *Bracken County News* from 1993 to 1999. Between 1995 and 1997 he published three books, and in 1997, was invited to be the opening speaker at the Northern Kentucky University History Day Conference.

John began collecting radios and phonographs when he was thirteen years old, and his current collection of over 200 items includes numerous pieces of Cincinnati radio history, including a large collection of radio ephemera. In addition to radios, he collects and restores early A and B power supplies and battery chargers. When John became interested in Cincinnati radio manufacturing he chose Kodel as the first project. He spent numerous hours researching and collecting information from newspapers and magazines concerning
the development and history of Kodel and related companies. Since then, he has written five other Cincinnati radio manufacturer histories, and is currently completing his research on Cleartone. John is planning to publish a book on the subject in the future.

He is currently a board member and chairman of the contest committee of the Mid South Antique Radio Club, and a member of AWA. John currently resides in Northern Kentucky with his wife Karen and son Josh.
The Challenge of Submarine Cable Development in the Mid-Nineteenth Century

Electrical telegraph systems were suggested as early as the third quarter of the eighteenth century, and serious experiments began soon thereafter. Commercially practical systems began to take shape in both America and Europe in the late 1830s and early 1840s as Cooke and Wheatstone in England and Morse in America introduced the electric telegraph to their respective markets. By the early 1850s the utility of these systems had been proven, and extensive networks of telegraph wire began to blanket Europe and the populated sections of the United States. In England and the Continent the need to connect the various countries and parts of countries separated by water soon became apparent. Similarly in America the need to close gaps created by the larger rivers that would not be spanned by bridges for several decades was as keenly felt.

The technical challenges were truly daunting. While the average citizen viewed the landline telegraph as it existed in 1850 with awe, and many considered it more magic than science, it was primitive and low-tech compared with what would be required to girdle the earth. The technology that would be required for a submarine cable system was several orders of magnitude more difficult than that required for a landline system. It was almost like asking Orville and Wilbur Wright in 1903, just after the first successful flight of the Wright flyer, to produce a complete space station and shuttle system. In 1850 submarine cables were definitely far beyond the state of the art.

Consider that in 1850 there were no generally accepted standards for electrical quantities like volts, amps, ohms, and joules. While it was understood that underwater wire would have to be insulated, it was yet to be determined that insulation that worked well over land did not necessarily work well under water, and insulation that worked under water might not work as well in air. The short underwater lines used
between the various islands of the United Kingdom and the European continent worked using the standard Morse or Cooke/Wheatstone systems then in use, albeit at much slower rates, but it was soon discovered that standard landline instruments could not be used over the vast distances required to span the Atlantic.

Quality control was another issue. For instance wire specified at #14 British Wire Gauge (BWG) might vary plus or minus several gauges in a mile. Much closer tolerances than conventional practice would be required. Also underwater cable was laid, or twisted, in much the same manner as rope. Trying to splice left hand twist and right hand twist cable together was an ugly business, and so a standard had to be established.

Paying-out equipment was another source of problems. Short lengths of submarine cables might seem stiff and unbendable, but improperly handled in long lengths, they could and did get loose and cause a backlash just as complex as one made with light nylon line on a fisherman's casting reel. Cable was difficult and expensive to build, so initially the tendency was to lay cable with as little slack as possible. This resulted in cable that was stretched across underwater ridges, and naturally it chafed, or in shallower water was made vulnerable to dragging anchors or trawling gear. However, if the cable was laid with too much slack it was subject to fouling and was wasteful of an expensive product.

Paying-out gear had to be developed to allow the stiff cable to slide into the water fast enough to lay on the bottom of the ocean without undue stress but be able to keep the cable paying out slowly enough not to run out before the destination was reached or to foul itself. This machinery had to be able to slow the cable payout to a dead stop if needed to permit splicing on new cable, but it had to brake the cable slowly enough not to cause the cable to snap. The paying-out gear had to meet all these criteria without becoming so fouled with tar (or other typical underwater cable coating) that the machine could no longer function. In addition to the cable laying technology, electrical apparatus that could transmit and more especially, receive the faint pulses had to be invented.

There have been literally dozens of accounts covering the history of submarine cables and the engineering genius, personal courage, and the risk of wealth and prestige required to wire the world. It is not my intent to rehash ground that has been so thoroughly covered. Instead,
I have chosen to provide a detailed time line for the construction of the various submarine cables and also include maps that show the evolution of the underwater telegraph systems that girdle the earth furnishing world-wide communications. This time line with additions, corrections, and slight rewording, has been adapted from an early book: *The All Red Line, The Annals and Aims of The Pacific Cable Project*, edited by George Johnson and published by James Hope & Sons, Ottawa in 1903. This detailed chronology provides a capsule history of submarine telegraph cable development.

For those wishing to delve more deeply into cable history, I have also included an extensive bibliography, derived from my personal
library, with additions from other sources. The figures that accompany this article show how undersea cables have proliferated since the first cable was laid.

**Time Line**

1795  Submarine telegraphy suggested by Salva, a Spaniard, before the Barcelona Academy of Sciences.
1797  Salva proposed submarine communication between Barcelona and the Island of Majorca.
1803  Aldini, nephew of Galvani, performed experiments in the transmission of electricity under the sea, near Calais, France.
1812  Schilling ignited gunpowder by electricity transmitted through a cable under the Neva River, near St. Petersburg, Russia.
1813  John Robert Sharpe, of England, transmitted electric signals through seven miles of underwater cable.
1838  Colonel Paisley, R.E., experimentally demonstrated practical underwater telegraphy at Chatterton.
1839  O'Shaughnessy, Director of the East India Company's telegraph system, transmitted telegraphic signals through insulated wire under the River Hughli, in India.
1842  Prof. Samuel Morse transmitted electric currents and signals between Castle Garden and Governor's Island, New York Harbor.
1845  Ezra Cornell operated 12 miles of copper wire in the Hudson River, insulating the wires in cotton and enclosing them in lead pipe.
1846  Charles West was granted permission to establish telegraphic communication between Dover and Calais, via the English Channel.
1850  Submarine telegraph lines were laid across the English Channel and worked for a time, ceasing from insulation failure.
1851  English and French capitalists laid across the English Channel a cable containing four copper wires insulated with gutta
percha, surrounded by tarred hemp, and protected by ten galvanized iron wires spirally wound around it.

1853 Six submarine telegraph cables were laid connecting England with Ireland, Scotland, and the continent of Europe at Belgium and Holland. The first two Anglo-Irish cables failed, being either too light for the job or being so heavy that they ran off the paying-out gear too fast and were exhausted before reaching the opposite shore.

1854 Five additional cables were laid in European waters.

1855 F. N. Gisborne and Cyrus Field proposed and then laid a cable between Newfoundland and Cape Breton, Nova Scotia (85 miles). Another cable was laid that year from Spezia, Italy, to Corsica, at a depth of 600 feet. Field also proposed an Atlantic Cable and began to solicit support from financiers in both England and America.

1857 Charles Bright, J. W. Brett and others from England, and Cyrus Field, from the United States, made the first attempt to lay a submarine cable across the Atlantic Ocean. The estimated length of the cable was 2,500 miles. The work was abandoned after 255 miles had been laid westward from Ireland when the cable broke.

1858 A second trans-Atlantic attempt by the same team was made. The British naval vessel, Agamemnon, and the United States naval vessel, the Niagara, each carrying one half of the cable, proceeded to mid ocean, spliced ends, and going in opposite directions, reached Newfoundland and Ireland the same day. This cable carried 730 messages, and then ceased working after one month. It cost $1,256,250. During this same period cable was being laid to connect France to its colony in Algeria via Italy.

1859 Submarine cable was laid to connect England with British India through the Red and Arabian seas, but soon proved a failure.

1860 The British Board of Trade appointed a committee to study the subject of submarine telegraphy. The committee reported in favor of further efforts. Also this year an alternate route for the Atlantic Cable was proposed. The route was to run from northern Scotland through the Faroe Islands, Iceland, Greenland, and Labrador enroute to Nova Scotia. It would have made each leg of the route shorter, but the cable landing
sites would be prone to ice damage, not to mention the cost of building and providing crews for several additional relay stations in harsh remote locations.

1861 A submarine telegraph cable was laid from Malta to Alexandria, Egypt, with intermediate landing places. It proved a permanent success.

1862 A submarine cable across the Mediterranean Sea from France to Algeria was a failure.

1864 The government of India constructed a cable line to connect India and England. The submerged line in the Arabian Sea and the Persian Gulf had a total length of 1,450 miles, with three intermediate landing places. It was a success, and for the first time England and India were telegraphically connected.

1865 Another (unsuccessful) attempt was made to girdle the Atlantic between Ireland and Newfoundland.
Still another effort to bridge the Atlantic by cable resulted in a complete success. The *Great Eastern* steamship paid out the cable from Ireland to Newfoundland in 14 days. Electric communication between Europe and America was established and has continued. The *Great Eastern*, after landing the Newfoundland end, returned to the spot where the 1865 cable was lost, and after 18 days' effort, secured the end from a depth of 11,000 feet, spliced it to a new cable, steamed to Newfoundland and landed the cable, thus completing the second successful line of communication. The length between Trinity Bay, Newfoundland and Valentia, Ireland, is over 1,600 miles. The transmission rate over these cables was at first only 8 words per minute, but increased to 15 wpm with improvements to receiving equipment and operator technique.

A second Anglo-Mediterranean line from Malta to Alexandria was laid and proved successful.

The first French Atlantic cable was laid from Brest, France, to Duxbury, Cape Cod, Massachusetts, and proved a success. Tasmania was connected with the Australian continent by cable.

Cables were laid by the Great Northern Telegraph Company along the eastern coast of Asia, connecting Hong Kong, Shanghai and Nagasaki (Japan) with the terminus of an overland telegraph line from St. Petersburg, through Russia and Siberia, to Vladivostok.

Duplex operation was applied to submarine telegraph lines, nearly doubling their capacity. A fourth cable was laid from Europe to the United States, by the Direct Telegraph Company. This cable, landed in Rye, New Hampshire, was the last trans-Atlantic cable to be front-page news in a national newspaper, *The Harper's Weekly*, albeit they were two and a half weeks premature with the news.

Cable was laid between Australia and New Zealand.

Port Natal and the Cape of Good Hope were joined by cable, and lines were extended along the east coast of Africa.

A new French cable was laid connecting France with America. A duplicate cable was laid from Penang to Port Darwin.
By 1930 dozens of submarine cables had been installed around the world. This figure shows cables spanning the North Atlantic along with connections to Africa and South America. This illustration and those that follow are taken from a circa 1930 edition of the *Western Union Telegraph Company Cable and Radio Tariff Book*. When scanned and printed in this reduced size, the details suffer. Nevertheless, the figure vividly demonstrates how submarine cables had proliferated by 1930.

1881 American Telegraph and Cable Co. laid a new trans-Atlantic line.
1882 American Telegraph and Cable Co. laid a second trans-Atlantic line. Lines were also laid along the west coast of South America.
1884 Mackay-Bennett Commercial Cable Co. laid two transatlantic lines.
1885 The West Coast of Africa was further supplied with cables.
1886 Italy was connected with various adjacent islands by cables.
1887 The French West Indies were connected with French Guiana and Venezuela.
1890 Halifox, N.S. and Bermuda were connected by cable. On July 1 the first message was sent; through water 17,000 feet deep. A duplicate New Zealand-Sydney cable opened.
1891 The French Government contracted for cable lines from Marseilles to Oran and Tunis.
1892 Cable was laid across the South Atlantic, from the west coast of Africa to Pernambuco, Brazil.
1893 Australia and the French colony of New Caledonia were connected by cable~800 miles.
1894 Two north trans-Atlantic cables were laid.
1896 Cable was laid from New York to Cape Haitian, Haiti. Also, a southern line to the British Windward Islands and South America, with a depth in places of 18,000 feet.
1898 The Halifax-Bermuda line was extended to Jamaica.
1901 Cable was laid from England to Australia, via the Cape of Good Hope, Mauritius, Rodrigues Island, Cocos and Freemantle; total length: 15,000 miles.
1902 The first cable across the Pacific Ocean was installed this year. Cable was laid from Vancouver Island, Canada, to Fanning Island, 3,654 miles; from Fanning Island to Fiji, 2181 miles; from Fiji to Norfolk Island, 1019 miles; from Norfolk Island to New Zealand, 513 miles; and from New Zealand to Australia, 906 miles; a total of 8,272 miles.
1903 Cable was laid from California to the Hawaiian Islands, January 1st.
1956 The first telephone cable from Europe to America was laid from Scotland to Newfoundland.
1964 The first telephone cable between the United States and Japan was laid, 5000 miles.
2004 The telegraph was already in decline at the beginning of the twentieth century as the telephone began to supplant it and skilled Morse operators were being replaced by teletype machines. By the 1960s the traditional telegraph system had become extinct, but the great world-wide ocean cable system was able to transition to the realities of the modern world. Copper wire cable that could carry only a few telegraph circuits at a time or a couple of dozen telephone conversations at a given moment, have been replaced by fiber optics.
Submarine cable installations around South America circa 1930. The large number of cables interconnecting major coastal cities suggests that by this time, the cost of submarine cables had dropped substantially relative to the first installations. (From the *Western Union Telegraph Company Cable and Tariff Book.*)
cables that can accommodate hundreds of thousands of voice, data, and video circuits simultaneously. New cables are being planned to China, South America, and Europe and each cable will be capable of handling four million telephone calls simultaneously. John Gordon Steele in his book, *A Thread Across the Ocean*, states that "Even with the advent of satellites, transoceanic communications is still largely by cable. Satellites, subject to solar 'weather,' account for only about 30 percent of global communications."

**Bibliography**

Note: Entries followed by an asterisk (*) have been compiled from various book sellers' catalogues. Entries followed by a double asterisk (**) have been compiled from the website of FTL Design (www.ftldesign.com), an excellent online museum of the Atlantic Cable as well as other engineering marvels. In some cases the citations are incomplete because I was unable to obtain the missing information. However, I chose to include them in the belief that even partial citations could be useful to other historians.

In addition to the books and journals cited here, I have also included in this article lists of music, patents, photos, and other cable-related items to which I have access. The variety of such materials that can be uncovered by those collectors and cable historians willing to hunt for them is quite remarkable.


Atlantic Telegraph Company. *Atlantic Telegraph Company Acts; 1845 - 1867 with letters to and from Mr. Fields laid in; with Articles of Agreement for the Union, and Protection and Improvement of Certain Telegraph Lines in North America laid in; c1867 Atlantic Telegraph Company a History of Preliminary Experimental Proceedings and a Descriptive Account of the Present State &
Prospects of the Undertaking. Published by Order of the Directors of the Company. London: Jarrold and Sons, 1857, 69 p

Atlantic Telegraph Company. Atlantic Telegraph Company Reports 1857 to 1868 (Compilation of minutes of the meetings of the Board of Directors of the Atlantic Telegraph Company); London: Atlantic Telegraph Company, 1868, unpaginated.


Bell, Mrs. Alexander Graham. Just an Incident Being a Story Founded on Fact, A Series of Tableaux Vivants To Be Performed By the Members of the Young Ladies' Club of Baddeck at Beinn Bhreagh September 18, 1913 at 8 PM. Baddeck, Nova Scotia: Self Published, 1913, 24 p. (A play by the wife of the inventor of the telephone about an early incident on the first Atlantic Cable.)


Briggs, Charles F., and Augustus Maverick. The Story of the
Submarine cables in the Caribbean circa 1930. By 1930 the islands of the Caribbean were well connected to the rest of the world. (From the Western Union Telegraph Company Cable and Tariff Book.)


Bright, Charles. *Personal Scrap Book.* (A large folio consisting of over 100 pages of news clippings, prospectus, annual reports, Acts of Parliament, maps, etc., with all items related to telegraphy in general, with a large emphasis on submarine cables. The scrapbook appears to have been compiled in 1860, and has Bright's calling card affixed to the inside of the front cover.)


Bright, Charles. *The Life Story of Sir Charles Tilston Bright.* London:
Archibald Constable & Company Ltd., 1910, 478 p. (A one-volume condensed version of the 1890s two-volume set.)

Bright, Charles. Imperial Telegraphic Communication. London: P.S. King & Son, 1911, 212 p. **

Bright, Edward B. The Electric Telegraph by Dr. Lardner. London: 1867, 272 p. **


Bush, Richard J. Reindeer, Dogs, and Snow-Shoes: A Journal of Siberian Travel and Explorations Made in the Years 1865, 1866, and 1867. New York: Harper & Brothers, 1871, 529 p. (An account of Western Union's aborted attempt to connect America and Europe by way of Alaska to Siberia by cable and Siberia to Europe overland.)


Submarine cable routings circa 1930, showing connections between Europe and Africa. (From the Western Union Telegraph Company Cable and Tariff Book.)


Collins, Perry McD. *Explorations of the Amoor River* (Letter of the Secretary of State to the House of Representatives regarding the exploration of Siberian Russia and projecting a telegraph line from America to Europe via Alaska and Asiatic Russia.) Washington, DC: Government Printing Office, 1858, 67 p. (plus three fold-out maps).

Collins, Perry McD. *Communication from the Secretary of State to chairman of Committee on Commerce relative to Telegraphic communication between the eastern and western continents.* Washington, DC: Government Printing Office, 1864, 7 p.


Collins, Perry McD. *Mr. Latham made the following Report to accompany bill S. 205.* (Re: Collins memorial to Congress for a survey of the North Pacific Ocean to facilitate an overland telegraph to Europe via Asiatic Russia.) Washington, DC: Government Printing Office, 1862, 9 p.

Commercial Cable Co. *From the Staff of the Commercial Cable Co to Its President John W. Mackay.* Commercial Cable Co., 1888, unpaginated.


Cornell, A. *True and Firm - Biography of Ezra Cornell Founder of*
Submarine cable routings circa 1930, showing connections to Australia, New Zealand, and Southeast Asia. (From the Western Union Telegraph Company Cable and Tariff Book.)


Eastern Associated Telegraph Companies. *Fifty Years of "Via


Europe and America Report of the Proceedings at an Inauguration Banquet, Given by Mr. Cyrus W. Field, of New York, at the Palace Hotel, Buckingham Gate, on Friday the 15th April 1864, in Commemoration of the Renewal by the Atlantic Telegraph Company, of Their Efforts to Unite Ireland and Newfoundland, by means of a Submarine Electric Telegraph Cable. London: Printed for private circulation only, 1864, 32 p.


Field, Cyrus. The Atlantic Telegraph (a prospectus). London: 1856, 20 p.**


Field, Cyrus. *Twenty-Seventh Anniversary of the First Atlantic Cable. Mr. Cyrus W. Field's Banquet at the Star and Garter Hotel, Richmond, on August 5th, 1885*. London: 1886, 32 p.


Gannett, Ezra S. *The Atlantic Telegraph: a Discourse Delivered in the First Church, August 8, 1858*. Boston: Crosby, Nichols, and Company, 1858, 19 p.


*The Great Eastern; An Illustrated Description of the Great Steamship*. London: 1859, 33 p.**

Gurney, Samuel. *Epitome of Proceedings at a Telegraphic Soiree.* London: 1862, 16 p.**


*Heart's Content Cable Station Provincial Historic Site.* Newfoundland: Newfoundland & Labrador Department of Tourism, 1 p.


Hoskiaer, Captain V.; *Laying and Repairing of Electric Telegraph Cables.* London: 1878, 71 p.**


Kelly, Hon. William D. *Oration Delivered at the Celebration of the
Laying of the Atlantic Cable, Held at Philadelphia, September 1, 1858. Philadelphia: 1858, 12 p.


Kennan, George. Tent Life in Siberia and Adventures Among the Koraks and Other Tribes in Kamtchatka and Northern Asia. (Another account by a principal of the Western Union's attempt at a Trans-Siberian telegraph line.) New York: G.P. Putnam's Sons, 1870, 425 p.


Trans-Pacific submarine cables circa 1930. (From the *Western Union Telegraph Company Cable and Tariff Book.*)
Broadsides and Ephemera

(A broadside is a fold-out sheet of paper, typically a poster or chart. Ephemera refers to printed matter not intended for retention, such as advertising brochures.) Given the number of such items that I have been able to locate roughly 150 years later, there must have been much of this type of material available in Cyrus Field’s time.

Atlantic Cable Celebration Albany, September 1, 1858. Decorative silk bookmark commemorative approximately 3" by 7." Slogans and illustration; Albany, NY, 1858.

Atlantic Cable Reward of Merit; Charles Magnus & Co; New York, 1858.

Field, Cyrus; decorative silk bookmark 3" by 4 1/2"; portrait of Field encircled by a cable.

Franklin, Benjamin; Franklin's Way To Wealth; New York; "Printed on the Ramage Press, while in procession, on the celebration of the Atlantic Cable, Sept 1, 1858."

The French Cable Station Museum; Cape Cod; 1 p. broadside (tourist brochure).

(continued on next page)
Broadsides and Ephemera - Continued

**Home Journal Extra;** "Messages exchanged between the Queen and the President via the Atlantic Cable on Aug 16, 1858;" *Home Journal;* 1858

**Submarine Cable; Submarine Cable...All Boats Must Keep Clear...;** Orleans, Mass.; The French Cable Co. (Poster posted next to water at points where the cable enters/exits the water.)

**Telegraph Chart;** New York; H.H. Lloyd & Co.; 1858 - Large (elephant) folio chart of the Atlantic Cable and images of Morse and telegraphic instruments, with extensive descriptive text.

**The Eighth Wonder of the World. The Atlantic Cable;** New York; Kimmel & Forester; 1866 - Folio hand colored stone lithograph commemorating the Atlantic Cable including texts of messages exchanged by President Andrew Johnson and Cyrus Field.

**Triumph of Science, the Three Great Powers of Peace & Progress, The Atlantic Telegraph; The Lightning Press, The Sewing Machine;** New York; Baker & Godwin, Printers; 1858; An advertisement for a sewing machine probably passed out at the Sept 1, 1858 parade in New York City celebrating the completion of the Atlantic Cable. Possibly printed on a wagon in the parade.


Newall, R. S. *Facts and Observations Relating to the Invention of the Submarine Cable.* London: E. & F. N. Spon, 1882, 8 p.**

Maps

London; The Electric & International Telegraph Company; Telegraph Map of England and Europe; c 1853; 1 p.

London; The Electric Telegraph Company's Map of Europe; 1869; 1 p.

The Western Union Telegraph Company; Cable and Radio Tariff Book, 1930; 47 p., 7 maps.


Rae, Thomas W. Passed Assistant Engineer; The Tactics of Submarine Telegraph Work. From "The Record of the United States Naval Institute." Washington, DC: U.S. Naval Institute, 1876, 55 p.
Music

These are examples of popular music involving cable themes. The fact that mid-nineteenth century popular music featured cable topics is evidence that trans-Atlantic cables truly captured the public's fancy at the time.


Fluegel, Herman. Atlantic Cable Tones, Chicago: Herman Fluegel, 1866.


Mazziotti, R. Atlantic Telegraph Gallop, 1867.


Talexy, A. Atlantic Telegraph Polka, Boston: Oliver Ditson & Co., 1858. (Cover has hand colored stone lithograph of the cable ships and a colored map of the cable route.)


Wheeler, Cervase. The Song of the Ocean Telegraph to be Sung by Everyone, New York: Wm Dressler, 1858, 8 p.


Roux, M. F.-L. Etude sur La Fabrication Et La Pose des Cables Electriques Sous Marins. Paris: Librairie Maritime Et Scientifique,
Periodicals

The Illustrated London News, Frank Leslie's Illustrated Newspaper, and Harper's Weekly all carried extensive coverage, including numerous woodcut illustrations, on the subject of the Atlantic Cable, between 1856 and the 1870s. Local newspapers also are likely to carry coverage of the cable laying, especially during the key years 1857-58 and 1865-66. The Direct Cable Company cable of 1874 appears to have been the last cable to get mention on the front page of a national paper, but locally important cables likely received extensive coverage in their home locality. Trade magazines and periodicals such as The Scientific American and in the 20th century, Popular Science, are good sources.

1965, 52 p.
Rowett, W. The Ocean Telegraph Cable: Its Construction, the Regulation of its Specific Gravity, and Submersion Explained. London: Sampson Low, Son & Marston, 1865, 125 p.**


Photos

Sir Charles T. Bright, head and shoulders image; Kingston, Jamaica; 1873 autographed by Bright on the reverse.

Sir Edward B. Bright, head and shoulders image; No back stamp; Dated 1873 in manuscript autographed by Bright on reverse.

Davis; stereograph: Cable Ship Faraday; Portsmouth, NH; 1874; stereo photo of the Faraday at anchor in Portsmouth harbor just prior to the completion of the Direct Cable Co. cable in July 1874.

Cabinet photo, 8 X 10; cable ship Faraday at anchor. Probably in Portsmouth Harbor. Photo unsigned, but likely Davis Bros.

Cyrus West Field; Field standing next to globe with length of cable; New York; E & H.T. Anthony from a Brady negative; c 1860s.

Cyrus West Field; head and shoulders view; London; John & Charles Watkins; c 1860s.

Great Eastern Steam Ship; at anchor in Liverpool Harbor; c 1870.

Mathew Fontaine Maury; Maury full figure seated; New York; E & H.T. Anthony, from a Brady negative; c1860s.

Samuel F.B. Morse; Morse in later years with his medals; New York; Sarony; c 1860s.

Samuel F.B. Morse; Morse standing with a Morse register; New York; E. Anthony from a Brady negative; c 1850s.

Saward, George. Deep Sea Telegraphs; Their Past History and Future Progress. London: 1861, 48 p.**

Saward, George. The Trans-Atlantic Submarine Telegraph. London: Printed for Private Circulation, 1878, 80 p.**
Patents

Scott, George of Wiscasset ME. *Apparatus for Paying Out Telegraph Cable;* Patent No. 21,371; Washington, DC; August 31, 1858. The patentee's copy; large (elephant) folio partially printed document with U.S. Patent Office seal, with original drawing of paying out machinery on linen drafting paper and containing the signatures of the Secretary of the Interior, the Commissioner of Patents, and George Scott.

Morse, S. E., and Morse, G. L. of Harrison, NJ. *Improvements in Submarine Telegraph Cable;* Patent No. 66,613; Washington, DC, July 9, 1867. The patentee's copy, large folio partially printed document with U.S. Patent Office seal, with four large (elephant) folio original drawings of the machinery on linen drafting papers and containing the signatures of the Secretary of the Interior, the Commissioner of Patents, Sidney E. Morse and G. Livingston Morse (Samuel F.B. Morse's brother and nephew respectively).


Scott, R. Bruce. *Gentleman on Imperial Service.* Victoria, Australia: Sononis Press, 1994, 131 p.**


Siemens, Scott J. D. *Siemens Brothers 1858-1958.* London:
Weidenfeld and Nicholson, 1958, 257 p.**

Siemens, Werner, and C. W. Siemens. *Outline of the Principles and Practice Involved in Dealing with the Electrical Conditions of Submarine Electric Telegraphs.* London: 1860, 7 p.**


*Souvenir of the Inaugural Fete, In Commemoration of the Opening of Direct Submarine Telegraph with India.* London: 1870.**


Stephens, J. H., Editor. *Text Book on Telegraph Cable Engineering.*


Thorp, G. Manuscript letter describing a visit to the Cable Ship Faraday while she was moored in Portsmouth, N.H. harbor. New Castle, NH: 1874.


Van Rensselaer, Cortlandt. Signals From the Atlantic Cable. An Address Delivered at the Telegraphic Celebration, September 1st,


**About the Author:**

Bill Holly was born in Middletown, New York, and raised in Colonie, New York (near Albany). He joined the U.S. Coast Guard in 1957 and
graduated from radio school at the Coast Guard training center in Groton, Connecticut, in 1960. In his 22-year career he was stationed in the Great Lakes, Alaska, Florida, Puerto Rico, and New England, with fifteen years spent at sea on six different ships, including a short tour on the Coast Guard Cutter Eagle. After his retirement as a chief radioman in 1979 he began a second career as a master electrician in the maintenance department of the Portsmouth Regional Hospital, Portsmouth, New Hampshire, where he spent 21 years. Bill always had an interest in history, and in the early 1970s he began studying the history of early communications and collecting radio and telegraph artifacts. He has assembled a library related to radio and telegraph history that now stands at over seven hundred volumes and has collected several hundred pieces of related ephemera. He has previously published articles in *CQ, QST, Classic Toy Trains, The Old Timer's Bulletin (OTB)*, and written the official history of the Vibroplex Company; *The Vibroplex Co. Inc. 1890 to 1990*. Bill and his wife of 40 years, Fran, have two grown daughters who live and work in New Hampshire. Bill and Fran and their two cats live in Kittery Point, Maine, and work no more than is absolutely necessary.
This story begins with the formation of the Radio Corporation of America (RCA) in October 1919 from the American Marconi Company. General Electric (GE) and the U.S. Navy were key players.

Radio was, in 1919, primarily a point-to-point communications medium, although that would change a scant few years later. American Marconi's parent company in England had fallen behind in technology—the company still relied on spark transmitters in 1919. General Electric had the Alexanderson alternator, the best performing transmitter of the day. American Marconi had been negotiating with GE to obtain exclusive world rights to the alternator technology, but the Navy was reluctant to allow it. During World War I the U.S. Navy had taken control of all U.S.-based radio communication, and for a time the Navy had hoped that they might continue that control in peacetime. Had American Marconi been able to finalize a deal with GE for the rights to the Alexanderson alternator, it would have created a situation, as it then appeared from the American perspective, where effective control of radio transmission would reside in foreign hands.

The fear that a non-U.S. entity (Marconi) would control overseas radio communications, a technology deemed critical to U.S. national security, was so strong and so widely held that the American government (primarily the U.S. Navy Department), was prepared to allow a monopoly within the radio industry if that was the only way to keep control of radio in U.S. hands. President Woodrow Wilson, attending the 1919 Paris Peace Conference, accelerated the changes by sending...
a message to the director of naval communications "that he counted
on him to keep a careful watch on American interests in
radio" (Aitken, 1985, p. 280). This statement was later amplified to
mean that American national interests were at stake.

The negotiators for American radio interests at the time feared
British domination, but in so doing overestimated the strength of the
British economy after the war (Aitken, 1985). It has been suggested
that the American Marconi Company was expropriated by the U.S.
Government (Herron, 1969, for example), but most historians do not
describe it that way. Rather, it was more of a friendly corporate take-
over with the strong encouragement of the Navy. Aitken describes the
negotiation process in painstaking detail, and suggests that General
Electric eventually paid somewhat more than the market price for
American Marconi stock. On the other hand, it was widely recog-
nized that there was a strong political will to create an all-American
radio company after World War I, and this likely inflated the
perceived value of American Marconi stock in the transaction. In the
end, both parties seemed reasonably satisfied with the price per share.

The Navy had urged GE to act quickly. The initial moves were by
Owen Young, GE's Vice President, and Edward J. Nally, American
Marconi's Vice President, who met and concluded that a merger
would benefit them both. Under the arrangement, American Marconi
(to become RCA) would be the operating company, and General
Electric would focus on manufacturing. As the plan solidified, the
notion of a government radio monopoly under control of the Navy
faded (due apparently to effective congressional lobbying by David
Sarnoff, Nally's assistant at the time), and the idea of a private
monopoly took its place. In fact there was widespread dissatisfaction
with the way the government had run the public utilities during the
War. Public interest in a government-run radio monopoly was, no
doubt, overestimated by the Navy (Douglas, 1987).

The American Telephone & Telegraph Company, and its subsidiary
the Western Electric Company joined RCA in 1920. The
Westinghouse Electric & Manufacturing Company, and the United
Fruit Company and its subsidiary the Wireless Specialty Apparatus
Company, joined in 1921. A recent account of events leading up to the
formation of RCA is provided by Lewis (1991a). S. J. Douglas (1987)
and Howeth (1963) also provide helpful information regarding the
formation of RCA.
An earlier version written by an academic closer in time to the events and with the blessings of Sarnoff, by then president of RCA, is the historical volume *Big Business and Radio* (Archer, 1939). Archer emphasized that the agreement between the corporate entities, formulated between 1919 and 1921, contained two main matters of importance. First, the participants agreed to share access to each other's patents. This cross licensing agreement created a patent environment similar to that to which the companies had become accustomed during the War, and greatly facilitated the design and manufacture of equipment using the best known techniques of the time. The second important aspect of the agreement was the appointment of RCA as the sales outlet of the participating corporations. Structured this way, RCA could overcome the earlier competitive attitudes of its corporate partners, or at least partially overcome them, as we shall see.

Archer (1939) goes on to say that if the passing of commercial traffic from point to point had turned out to be the principal application of radio, as had been the underlying assumption during the formation of RCA, the company would have had trouble surviving. What occurred next, however, was the "Radio Boom" (broadcasting entertainment to the public). Initially RCA was unprepared for it.

Archer wrote a relatively non-critical view of the industry, with the overt cooperation of the RCA president. Consequently, his book is highly sympathetic to RCA. Let me digress to yet another contemporary view. While Archer presents a rosy picture of Sarnoff's role in the development of RCA, Gutterman (1968) out does him. Sarnoff cooperated in the creation of Gutterman's biography, which states, for example, "World renowned as 'The Father of Radio and Television,' Sarnoff stands by himself among the great American men of wisdom. ... In the Radio Corporation of America, David Sarnoff created out of many diverse units one great corporate institution covering the entire field of electronics communication, from research through production. ... Guiding genius of a great organization, no other business leader has done more for the enlightenment and independence of American thought through radio broadcasting and television. His life is a tribute to the dynamics of freedom." (pp. 9, 10)." Gutterman goes on to include testimonials from 34 eminent Americans, presumably largely or entirely fiction. To his credit, even Sarnoff found the exaggerated praise in the book offensive, and after seeing it, tried vigorously to recall the sold copies.
Still, it was Sarnoff's position that the organizational strategy of RCA was important to present to the world as largely a product of his own foresight, even if he had to revise history somewhat to have the record say so (Lewis, 1991a; 1991b). There remains a possibility, therefore, that if in the conceived organization some aspects did not go entirely according to plan, we may not have heard of it. Certainly, Archer and Gutterman did not dwell on RCA's failures.

Manufacturing for RCA

In the 1919 agreement General Electric was responsible for manufacturing equipment sold by RCA. (What little manufacturing capability American Marconi had was absorbed by GE.) When Westinghouse joined the group, responsibility for manufacturing was reallocated, with sixty percent to General Electric and forty percent to Westinghouse. By 1921 broadcasting to the public, and the resulting demand for receivers and transmitters, was increasingly being recognized as a possible business opportunity. Among the main partners in RCA, Western Electric was to manufacture broadcast transmitters, and General Electric and Westinghouse were to manufacture receivers. Wireless Specialty Apparatus (WSA) made only a negligible number of receivers.

Anderson (1990) describes some of the early production at General Electric. Archer (1939) details the early broadcast receiver production of GE and Westinghouse (Table 1). The plan at the time was to have each of these companies submit designs of new receivers to a Receiver Manufacturing and Design Committee at RCA for approval. If approved, designs were to be manufactured by both General Electric and Westinghouse to the same specifications—RCA specifications. Archer reports that RCA had initial difficulty in coordinating manufacturing standards between General Electric and Westinghouse, a factor in the relative advantage by the independent manufacturers of the time. Competitors such as Atwater Kent, Crosley, and Zenith had less internal bureaucracy, and so got a head start in the home broadcast marketplace while RCA was still working out its internal policies.

The requirement that GE and Westinghouse engineers submit plans to the Receiver Manufacturing and Design Committee for approval apparently caused considerable turmoil. Barnum (1991) reports that
Table 1
Company of Manufacture for Early RCA Sets
(Adapted from a 1923 price list table in Archer's
*Big Business and Radio*, page 16.)

<table>
<thead>
<tr>
<th>Model</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiola I</td>
<td>GE</td>
</tr>
<tr>
<td>Radiola II</td>
<td>GE</td>
</tr>
<tr>
<td>Radiola IV</td>
<td>GE</td>
</tr>
<tr>
<td>Radiola V</td>
<td>GE</td>
</tr>
<tr>
<td>Radiola VI</td>
<td>GE</td>
</tr>
<tr>
<td>Radiola Senior</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>AC Two-Stage Amplifier</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>RS</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>RG Radiola Grand</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>RT Antenna Coupler</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>RA Tuner</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>AR Radio Amplifier</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>DA Detector-Amplifier</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>AA 1520 Radio Amplifier</td>
<td>GE</td>
</tr>
<tr>
<td>AA 485</td>
<td>Wireless Specialty Apparatus</td>
</tr>
</tbody>
</table>
"RCA faced tremendous coordination problems as a result of the dispersed competing operations" (p. 142). Alfred Goldsmith was in charge of the RCA Technical and Test Department at Van Cortlandt Park in New York City. Receiver prototypes submitted independently by GE and Westinghouse were tested and the results reported back to the companies. Manufacturing could not commence until the Receiver Manufacturing and Design Committee gave its approval. "However, due to diverse opinions among the various representatives of GE, Westinghouse, and RCA, agreements were difficult to reach … As a result, progress in product development and manufacturing was slow for the next several years" (Barnum, 1991, p. 143).

Under these circumstances it is not surprising that most of the histories of RCA and its players do not mention the relative difficulty of the dual manufacturing of receivers. The purpose of this paper is to determine the extent to which particular models of broadcast receivers in the first decade of RCA were manufactured both by General Electric and Westinghouse to common specifications, or whether there was a residual corporate rivalry that resulted in some models being made exclusively by one company and some by the other.

Methods

Several approaches were used to trace the provenance of receivers. First was the direct mention in credible published sources such as Archer, *Big Business and Radio* (1939), RCA, *Radio Enters the Home* (1922), and Barnum, *His Master's Voice* *In America* (1991). Dr. John Anderson, retired from General Electric, undertook to search relevant material from the Schenectady [NY] Museum, which houses the General Electric archives. He suggested that broadcast receiver manuals that were printed in Schenectady would be an indicator that the set was manufactured there. He suggested also that receivers mentioned in the General Electric *Works News* (company newsletter) would likely have been manufactured by General Electric. Finally he manually searched photo cards in the Schenectady Museum, suggesting that receivers with more photos would likely have been manufactured by General Electric, compared to receivers with no or fewer archival photos. He did not suggest an absolute cutoff number of photos that would indicate General Electric manufacture. Regrettably, no correspondingly valuable information has been recovered from Westinghouse.
Collecting early broadcast receivers in Canada gives one a slightly different perspective on the manufacturing efforts of GE and Westinghouse in comparison to each other. It occurred to several of us Canadian collectors that the subsidiaries of General Electric and Westinghouse in Canada sold broadcast receivers in the 1920s, and RCA did not operate in Canada in that decade. Accordingly, the subsidiaries, Canadian General Electric and Canadian Westinghouse, each sold receivers labeled with their own corporate names.

Further, we assumed that Canadian General Electric would not be motivated to sell in Canada a receiver that had been manufactured by Westinghouse in the U.S., nor would Canadian Westinghouse be motivated to sell a receiver in Canada that had been made by General Electric in the U.S. We therefore inferred that the labeling of receivers in Canada would be an important clue to the manufacture of receivers in the U.S. To further check on the connection between receivers sold in Canada and similar receivers made in the U.S. by the parent companies and sold under the RCA label, we checked whether service schematics in Rider manuals and in Radio College of Canada (RCC) manuals were identical for sets bearing the same model number.

A tabulation of all of these indicators of provenance of manufacture is shown in Table 2 (pages 114 to 117). The table attempts to cover all major models of receiver sold by RCA between 1921 and 1929. There were a few models made by the Canadian subsidiaries and not by the U.S. parent companies and these are also included. A few corporate idiosyncrasies complicate the picture. Canadian General Electric, when it offers receivers in Canada matching those with RCA model numbers in the US, tends usually to offer a receiver that is identical to the RCA model. Canadian Westinghouse on the other hand, when offering receivers matching those with RCA model numbers, more often tends to provide receivers with design modifications compared to the RCA model.

Results

Early Sets with Manufacturers Identified by RCA

As will be seen in Tables 1 and 2, there is a group of receivers manufactured in the years 1921-1923 whose company of manufacture is identified by Archer (1939, pages 15, 16). Since Archer was writing fewer than twenty years after the events, and since he had generous access to RCA documents, it appears safe to assume that this
Table 2
Principal Broadcast Receivers Sold by RCA
Between 1921 and 1929

<table>
<thead>
<tr>
<th>RCA Designation, (Year), [Table Footnote Numbers], [Number of photo cards per Anderson]</th>
<th>Made by</th>
<th>Canadian Designation and Manufacturer</th>
<th>Rider &amp; RCC Agree?</th>
<th>Fig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA 1400 (1922) [1, 2, 3, 6{1}]</td>
<td>GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA1520 (1922)[1, 6{1}]</td>
<td>GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR 1300 (1922)[1, 2, 3]</td>
<td>GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR 1375 (1922)[1, 2]</td>
<td>WSA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeriola Junior (1921) [1, 2, 3]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeriola Grand (1922) [1, 2, 3]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeriola/Radiola AC (1922) [1]</td>
<td>West.</td>
<td>Radiola AC (Cdn. West.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeriola/Radiola RS (1923) [1]</td>
<td>West.</td>
<td>Aeriola RS (Cdn. West.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aeriola/Radiola Sr.(1922) [1, 2, 3]</td>
<td>West.</td>
<td>Aeriola Sr. (Cdn. West.)</td>
<td>2, 3</td>
<td></td>
</tr>
<tr>
<td>DA (1921) [1, 2, 3]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA (1921) [1, 2, 3]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC (1921) [1, 2, 3]</td>
<td>West.</td>
<td>RC (Cdn. West.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola AR (1923)</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola Balanced Amp. (1924)</td>
<td>West.</td>
<td>Radiola Balanced Amp. (Cdn. Westinghouse)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Radiola Grand (1923)[1, 6 {1}]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola Regenoflex (1924)</td>
<td>West.</td>
<td>Radiola Regenoflex (Cdn. Westinghouse)</td>
<td>unknown</td>
<td>22</td>
</tr>
<tr>
<td>Radiola Sr. Amplifier (1923)[1]</td>
<td>West.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola Super AR 812 (1924) [4, 6 {121}]</td>
<td>GE</td>
<td>Radiola AR 812 (CGE)</td>
<td>unknown</td>
<td>12, 13</td>
</tr>
<tr>
<td>RCA Designation, (Year), [Table Footnote Numbers], [Number of photo cards per Anderson]</td>
<td>Made by</td>
<td>Canadian Designation and Manufacturer(s)</td>
<td>Rider &amp; RCC Agree?</td>
<td>Fig.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Radiola Super VIII (1924) [4, 6 [45]]</td>
<td>GE</td>
<td>Radiola Super VIII (CGE) Model 8 (Cdn. West.)</td>
<td>no</td>
<td>14</td>
</tr>
<tr>
<td>Radiola I (ER-753) (1922) [1, 2, 3, 5, 6 [23]]</td>
<td>GE</td>
<td>Model 118 (CGE)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Radiola II (1923) [1, 3, 4, 6 {17}]</td>
<td>GE</td>
<td>Radiola II (1923) [1, 3, 4, 6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola III (1924) [3, 6 {2}]</td>
<td>GE, West.</td>
<td>Radiola III (both CGE and Cdn. Westinghouse)</td>
<td>unknown/yes</td>
<td>4 - 9</td>
</tr>
<tr>
<td>Radiola IIIA (1924) [6 {2}]</td>
<td>GE, West.</td>
<td>Radiola IIIA (both CGE and Cdn. Westinghouse)</td>
<td>unknown/yes</td>
<td>10, 11</td>
</tr>
<tr>
<td>Radiola IV (1922) [1, 4, 6 {36}]</td>
<td>GE</td>
<td>Radiola IV (1922) [1, 4, 6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola V (1922) [1, 6 {?}]</td>
<td>GE</td>
<td>Radiola V (1922) [1, 6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola VI (1922) [1, 3, 6 {6}]</td>
<td>GE</td>
<td>Radiola VI (1922) [1, 3, 6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola VII (1923)</td>
<td>GE</td>
<td>Radiola VII (1923)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola VIIIB (1924) [6 {2}]</td>
<td>?</td>
<td>Radiola VIIIB (1924) [6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola IX (1923) [6{11}]</td>
<td>WSA</td>
<td>Radiola IX (1923) [6]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola X (1924) [6 {6}]</td>
<td>West.</td>
<td>Radiola X (Cdn. West.)</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>Radiola 16 (1927) [5, 6 {14}, 7]</td>
<td>GE</td>
<td>Radiola 16 (CGE), Model 16 (Cdn. West.) In 1928, Westinghouse renamed it the “Battery Operated” (see text)</td>
<td>yes/no</td>
<td>15, 16, 17</td>
</tr>
<tr>
<td>Radiola 17 (1927) [6 {26}, 7]</td>
<td>GE</td>
<td>Radiola 17 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 18 (1928) [6 {20}, 7]</td>
<td>GE</td>
<td>Radiola 18 (CGE). In 1927 Cdn. West. called it the “Batteryless Receiver.”</td>
<td>yes</td>
<td>18, 19, 21</td>
</tr>
<tr>
<td>Radiola 19 [6 {15}]</td>
<td>GE</td>
<td>Radiola 19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 20 (1925) [5, 6 {18}, 7]</td>
<td>GE, West.</td>
<td>Radiola 20 (both CGE and Cdn. Westinghouse)</td>
<td>yes/unknown</td>
<td></td>
</tr>
<tr>
<td>Radiola 21 (1929) [6 {8}, 7]</td>
<td>GE</td>
<td>Radiola 21 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

115
Table 2 (Continued)

<table>
<thead>
<tr>
<th>RCA Designation, (Year), [Table Footnote Numbers], (Number of photo cards per Anderson)</th>
<th>Made by</th>
<th>Canadian Designation and Manufacturer(s)</th>
<th>Rider &amp; RCC Agree?</th>
<th>Fig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiola 22 (1929) [6 {15}, 7]</td>
<td>GE</td>
<td>Radiola 22 (CGE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 24 (1925) [4, 6 {9}]</td>
<td>GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 25 (1925) [4, 6 {50}]</td>
<td>GE</td>
<td>Radiola 25 (CGE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 26 (1925) [5]</td>
<td>GE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 28 (1925) [4,5, 6 {45}, 7]</td>
<td>GE</td>
<td>Radiola 28 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 29 [6 {8}]</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 30 (1925)</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 30-A (1927) [4, 5, 6 {25}]</td>
<td>GE</td>
<td>Radiola 30-A (CGE)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Radiola 32 (1927) [5, 6 {18}]</td>
<td>GE</td>
<td>Radiola 32 (CGE)</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Radiola 33 (1929) [6 {6}, 7]</td>
<td>GE</td>
<td>Radiola 33 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 33 DC (1929)</td>
<td>GE?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 41 (1928)</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 44 (1929) [6 {23}, 7]</td>
<td>GE</td>
<td>Radiola 44 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 46 (1929) [6 {3}, 7]</td>
<td>GE</td>
<td>Radiola 46 CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 47 (1929) [7]</td>
<td>GE</td>
<td>Radiola 47 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 48 (1930)</td>
<td>?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 50 (1927) [6 {4}, 7]</td>
<td>GE</td>
<td>Radiola 50 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 51 (1928) [7]</td>
<td>GE</td>
<td>Radiola 51 (CGE)</td>
<td>yes</td>
<td>23, 24</td>
</tr>
<tr>
<td>Model 53 (Cdn. West., 1925)</td>
<td></td>
<td></td>
<td>yes</td>
<td>25</td>
</tr>
</tbody>
</table>
Table 2 (Continued)

<table>
<thead>
<tr>
<th>RCA Designation, (Year), [Footnote Numbers], [Number of photo cards per Anderson]</th>
<th>Made by</th>
<th>Canadian Designation and Manufacturer(s)</th>
<th>Rider &amp; RCC Agree?</th>
<th>Fig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiola 55 (1928) [6 {5}]</td>
<td>?</td>
<td>Model 55 (Cdn. West., 1925),</td>
<td>no</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 56 (Cdn. West., 1926)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 57B (Cdn. West., 1926)</td>
<td></td>
<td>27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 58 (Cdn. West., 1927)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiola 60 (1928) [6 {2},7]</td>
<td>GE</td>
<td>Radiola 60 (CGE), Model 60 (Westinghouse)</td>
<td>yes/no</td>
<td>28</td>
</tr>
<tr>
<td>Radiola 62 (1928) [7]</td>
<td>GE</td>
<td>Radiola 62 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 64 (1928) [7]</td>
<td>GE</td>
<td>Radiola 64 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 66 (1929) [6 {4}, 7]</td>
<td>GE</td>
<td>Radiola 66 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Radiola 67 (1929) [7]</td>
<td>GE</td>
<td>Radiola 67 (CGE)</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 69 (Cdn. West., 1929)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 89 (Cdn. West., 1929)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 93 (Cdn. West., 1925)</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 99 (Cdn. West., 1929)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Model 193 (Cdn. West. 1925)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Footnotes for Table 2 (refer to bibliography):

1. Archer (1939)
2. RCA (1922)
6. Anderson (2003) number of photo cards in Schenectady Museum
7. Schematics in Rider and Radio College of Canada manuals are identical
Information was accurate (Table 2, footnote 1). The RCA publication *Radio Enters the Home* also appeared before RCA adopted a policy of not identifying the corporate origins of receivers it sold. Accordingly, this book indicates the respective manufacturers (Table 2, footnote 2). Barnum (1981), who worked largely with source documents in the Hagley Museum, Wilmington, Delaware, is another credible source who essentially agrees with the others on the origins of early sets (Table 2, footnote 3).

*Information from the Schenectady Museum*

Instruction manuals printed in Schenectady (Table 2, footnote 4) are taken to indicate manufacture by GE. Mention in the *Works News* at General Electric is also taken as an indicator of manufacture by General Electric (Table 2, footnote 5). The number of photo cards in the Schenectady Museum has been recorded by Anderson (2003), and are shown in braces beside the footnote 6 references in Table 2. These numbers vary widely between models, and are taken to indicate likely manufacture by General Electric if greater than 2. (No such criterion number was suggested by Anderson.)

*Information from the Comparison of Rider and RCC manuals*

Comparing schematics in Rider radio manuals produced in the U.S. with those in the RCC manuals produced in Canada (Footnote 7 of Table 2) provides additional information about which Canadian models are similar or identical to their U.S. counterparts. The fourth column in Table 2 indicates whether the corresponding schematics are the same.

The pages that follow describe the similarities and differences of sets made in both the U.S. and in Canada. (The entries in Table 2 are alphabetical.)

The crystal set Model ER-753, later called the Radiola I, was made by General Electric according to several early sources which all agree. In Canada, CGE sold a crystal set (Model 118). Canadian Westinghouse did not make a crystal set. If we set out to confirm that General Electric and CGE both made these sets (we don't really need to confirm it), we can compare the appearance of the Radiola I with that of the CGE 118. Consider the CGE set in Fig. 1 in comparison to the Radiola I as pictured in Douglas, 1991, Vol. 3, page 14 or Bunis,
There are a few common features but also prominent differences. The Radiola I has a Perikon detector while the GCE 118 has a galena detector. They both have embossed black panels but the knob arrangement is different and the boxes are different. They have similar binding nuts and a similar tuning knob. We have to concede that the comparison of these two sets does not advance very well the argument for similar manufacture from General Electric and CGE.

The Aeriola Sr. is one of the early receivers that was identified as RCA in 1921, but also labeled as made by Westinghouse (Fig. 2). The Westinghouse subsidiary in Canada offered an identical set, except for labels that indicated manufacture by Canadian Westinghouse in Hamilton, Ontario (Fig. 3). The location of these labels on the Canadian set was in the paper lid instruction card, and on the tuning dial scaled 1 to 10. In fact the replacement dial scale was on an aluminum plate fixed on top of the original, which still indicated Westinghouse's East Springfield Works.

A confusing comparison surrounds the production of the Radiola III in 1924. The Canadian Westinghouse, RCA, and CGE versions are
Figure 2. Canadian Westinghouse Aeriola Sr. (Robert MacIntyre collection.)

Figure 3. Westinghouse Aeriola Sr. (Author’s collection.)
shown in Figs. 4, 5, and 6 respectively. They look quite similar externally, although the CGE model is finished in gold wash, rather than the nickel plating of the RCA and Canadian Westinghouse models. Also, both RCA and Canadian Westinghouse models used WD-11 tubes, while the CGE used UX-199 tubes. The undersides of the chassis are shown in Figs. 7, 8, and 9, respectively for Canadian Westinghouse, RCA, and CGE. Again, the Canadian Westinghouse and RCA models are visibly similar using identically shaped closed transformers and a row of cylindrical capacitors along the right hand edge, in contrast to the CGE, which uses a subassembly of wafer capacitors. The contacts to the rotating coils in the Canadian Westinghouse and RCA models are through small coil springs apparently of bronze, while the contacts to the rotating coils in the CGE model are through short lengths of Litz wire fed through the hollow rotating shaft.

All indications here point to the likelihood that Canadian Westinghouse adopted the RCA version of the Radiola III except for the panel engraving. The CGE version contained some modifications. Does this mean that Westinghouse took the lead in manufacturing the Radiola III for RCA in the U.S.? Possibly so. Also, Canadian Westinghouse was the only subsidiary of the RCA family to sell a Balanced Amplifier in Canada, as far as we know. The Radio College of Canada service manuals are not helpful in solving this puzzle. They contain a Canadian Westinghouse schematic that is identical to the RCA schematic shown in Rider. On the subject of the CGE circuit, they merely note that it corresponds to the Canadian Westinghouse circuit. Did Westinghouse manufacture the majority of, or all of, the Radiola IIIs obtained by RCA? On balance it would appear so, and Barnum (1991, p. 144) specifically says that they were designed by Westinghouse.

Both Westinghouse and GE subsidiaries offered the Radiola IIIA in Canada. The RCA model is shown in Douglas (1991, page 34) and in Bunis & Bunis (1992, page 157). The CGE Radiola IIIA was finished in gold wash, as was their Radiola III (see Fig. 10). The receiver used 199 tubes and inside used the same style of coil contacts, audio transformer and capacitors that distinguished the CGE Radiola III. The Canadian Westinghouse Radiola IIIA used WD-11 tubes, had nickel plated hardware, and in other respects looked like a Westinghouse product (see Fig. 11). A comparison of these two sets serves to reinforce the notion that Westinghouse was primarily
Figure 4. Canadian Westinghouse Radiola III. (Robert MacIntyre collection.)

Figure 5. RCA Radiola III. (Robert MacIntyre collection.)
responsible for the production of Radiola IIIA receivers for RCA, although GE may also have been involved. Were there some RCA Radiola III or IIIA models that used 199 tubes? None that we are aware of.

The Radiola Super, AR 812, was sold only by CGE in Canada. My example indicates RCA on the escutcheon and on both dial plates (see Fig. 12). The RCA model is shown in Douglas (1991, p. 28) and Bunis & Bunis (1995, p. 200). It is only on the battery instructions behind the battery doors that the company CGE is identified (Fig. 13). There was also a version of this CGE set that had the CGE logo on the tuning dials, and the version shown in the Canadian instruction book shows a set identified this way. The RCC manuals do not contain a schematic for this receiver. The other information we have about its provenance is from John Anderson, who reports that its manual was printed in Schenectady and that there are twelve photo cards for this receiver in the Schenectady museum. The weight of evidence appears to favor General Electric as the manufacturer for RCA.

Figure 6. CGE Radiola III. (Robert MacIntyre collection.)
Figure 7. Components side of Canadian Westinghouse Radiola III. (Robert MacIntyre collection.)

Figure 8. Components side of RCA Radiola III. (Robert MacIntyre collection.)
The Canadian Westinghouse Model 8 (Fig. 14) is another superhet modeled loosely after the RCA Radiola 28 (which was also sold in Canada). The RCA Radiola 28 is shown in Douglas (1991, page 41) and Bunis & Bunis (1995, page 158). The Model 8 schematic does not correspond to the RCA 28 schematic, and the Model 8 cabinet is of solid hardwood, probably walnut, whereas the Radiola 28 cabinet is veneered. The Canadian Westinghouse Model 8 does not correspond to any RCA model of which we are aware. In Table 2, the Model 8 is compared to the RCA Radiola Super VIII. All of the other indicators of provenance of the Super VIII favor manufacture by General Electric.

The RCA Radiola 16 appears from Table 2 to have been manufactured by General Electric. The RCA Radiola 16 appears in Douglas (1991, page 44) and in Bunis & Bunis (1995, p. 199). There
Figure 10. CGE Radiola IIIA. (Author’s collection.)

Figure 11. Canadian Westinghouse Radiola IIIA. (Author’s collection.)
Figure 12. CGE Radiola Super, Model AR 812. (Author’s collection.)

Figure 13. CGE Radiola Super, Model AR 812, back side of battery compartment doors. CGE is identified as the manufacturer on these labels. (Author’s collection.)
Figure 14. Canadian Westinghouse Model 8. (Author’s collection.)
is a corresponding Radiola 16 sold by CGE (see Fig. 15). On the bottom of the cabinet the CGE sticker appears to cover an RCA sticker of about the same size (not shown).

Canadian Westinghouse also made two receivers of types similar to the 16. One was called the Canadian Westinghouse 16 and was housed in a slightly larger cabinet than the CGE equivalent (Fig. 16). In other respects the CGE Radiola 16 and the Canadian Westinghouse 16 were very similar.

The other Canadian radio similar to the 16 was the Westinghouse Battery Operated. The Battery Operated appears equivalent to the previous two receivers but is contained in a box the same size as the Canadian Westinghouse 16 (Fig. 17). The likely origin of the name requires some explanation. Notice that the RCA Radiolas 16, 17 and 18 were all introduced around 1927. Radiolas 17 and 18 were light-socket operated AC receivers. In Canada the pioneer in light-socket operated radios was Ted Rogers (Chaplin, 2002), who used the trade name "Rogers Batteryless." Apparently the name was not registered as a trademark because Canadian Westinghouse launched a receiver similar to the RCA Radiola 17 but called the Westinghouse Batteryless Receiver (Fig. 18). In contrast then, Canadian Westinghouse appears to have labeled the latter part of its production run of Model 16 receivers as the Canadian Westinghouse Battery Operated.

To return to the likely manufacture of RCA receivers, there were CGE models of Radiolas 17 and 18. RCA Radiolas 17 and 18 are shown in Douglas (1991, p. 44) and Bunis & Bunis (1995, p. 199, Radiola 17 only). The CGE Radiola 18 pictured here (Fig. 19) is marked Canadian General Electric on its escutcheon (Fig. 20), but the paper tag under the cabinet covers what seems to be a dark brown RCA tag. Looking carefully at Fig. 21, the top edge of the dark sticker can be seen along the top of the CGE sticker. The indicators of manufacture of the RCA Radiola 17 and 18 in Table 2 seem to favor manufacture by General Electric. The fact that Canadian Westinghouse manufactured the Batteryless around the same time (Fig. 18), in a larger cabinet with a somewhat different design that has no corresponding RCA model, encourages but does not prove the inference that no Radiolas 17 or 18 were manufactured for RCA by Westinghouse.

The RCA Radiola Regenoflex has no indicators in Table 2 about its
Figure 15. CGE Radiola 16. (Robert MacIntyre collection.)

Figure 16. Canadian Westinghouse Model 16. (Author’s collection.)
Figure 17. Canadian Westinghouse Battery Operated. (Author’s collection.)

Figure 18. Canadian Westinghouse Batteryless Receiver. (Author’s collection.)
Figure 19. CGE Radiola 18. (Robert MacIntyre collection.)

Figure 20. Escutcheon of CGE Radiola 18. (Robert MacIntyre collection.)
manufacturing origin, and specifically none of the indicators that favor manufacture by General Electric (see Douglas, 1991, p. 32) and Bunis & Bunis (1992, p. 158). There was a Canadian Westinghouse Radiola Regenoflex (Fig. 22) offered for sale in Canada which appears identical to the RCA model except for the engraved escutcheon which is part of the Bakelite front panel. The existence of this model in Canada implies manufacture by Westinghouse for RCA.

The RCA Radiola 20 (Douglas, 1991 pages 40 and 43, and Bunis & Bunis, 1995, p. 199) certainly appears from the indicators in Table 2 to have been manufactured by General Electric. There was also a Canadian Westinghouse Radiola 20 sold in Canada, raising the possibility that Westinghouse also supplied some Radiola 20s to RCA.

The Radiola 50 and 51 were apparently made by General Electric for RCA in the U.S. according to the indications cited in Table 2. For illustrations see Douglas (1991, pages 44 and 47). Models of these receivers were also sold in Canada under the CGE label but not under

---

**Figure 21.** Paper tags under the CGE Radiola 18. (Robert MacIntyre collection.)
the Canadian Westinghouse label (see CGE Radiola 51 in Fig. 23). The schematics of the RCA models in Riders and the CGE models in the RCC manuals correspond exactly. Finally, the indications for Radiolas 17 and 18, the table model equivalents of these receivers, are entirely parallel. They also were sold only by CGE in Canada.

The paper label for the CGE Radiola 51 is shown in Fig. 24. In fact there are two labels pasted one over the other on the shelf behind the receiver. The top label indicates that the receiver was made in Canada by CGE. The bottom label is shown where the corner of the upper one has been peeled back. The lower label indicates that the set was offered for sale by RCA.

These duplicate paper labels, found on Radiolas 16, 18 and 51 in Canadian collections, and possibly on other models, indicate that likely complete models were exported to Canada, with Canadian escutcheon plates added either at the source or the destination. It seems unlikely that the addition of a nameplate would allow these receivers to be identified as made in Canada under government Customs rules, but possibly if sub-assemblies were shipped, this would have been allowed. The models we encountered that were so identified were all imported by CGE.

The Canadian Westinghouse 53 is a model advertised as having similar performance to the Radiola IIIA, but achieved with the use of only three tubes (see Fig. 25). The tubes were two UX-199s and one UX-120. Westinghouse or RCA sold no such corresponding set, and it is mentioned here only for completeness.

Canadian Westinghouse also offered at least three additional models similar to the Radiola 20. These were labeled the Canadian Westinghouse 55 (Fig. 26), the Canadian Westinghouse 57B (Fig. 27), and the Canadian Westinghouse 60 (Fig. 28). Two of these were housed in cabinets similar to the RCA Radiola 20 cabinet, and the third was in a similar but less elaborate cabinet. It is not entirely clear why the Canadian Westinghouse designers added this string of extra models, but it is consistent with their inclination to embellish on the designs handed to them by the parent company.

The Canadian Westinghouse 55 does not correspond to the RCA Radiola 55. The respective schematics do not match. There was no receiver marked Radiola 55 sold in Canada.
Figure 22. Canadian Westinghouse Radiola Regenoflex. (Author’s collection.)

Figure 23. CGE Radiola 51. (Author’s collection.)
Figure 24. Paper labels on the CGE Radiola 51. (Author’s collection.)

Figure 25. Canadian Westinghouse Model 53. (Author’s collection.)
Figure 26. Canadian Westinghouse Model 55. (Robert MacIntyre collection.)

Figure 27. Canadian Westinghouse Model 57B. (Author’s collection.)
There was a final set in this series, the CGE 93 (Fig. 29). This set did not correspond to an RCA model but rather to the Canadian Westinghouse 53, also apparently designed in Canada. As in the case of the CGE 53, this model is included only for completeness. It does not contribute to our indications of RCA manufacturing. It does, however, indicate that Canadian Westinghouse and CGE engineers were collaborating to some degree. The RCC manuals indicate that the circuits for the 53 and 93 correspond.

**Summary**

The essence of the information gleaned from the various sources is contained in Table 2 in the column headed "Made by:" There is essential agreement among the indicators on the subject of who made which receiver. The majority of them (38 in all) were made by General Electric and many fewer (18) were made by Westinghouse, with some overlap. Had we uncovered more detailed information from Westinghouse, the table might have been tilted at least some
Figure 29. CGE Model 93. (Author's collection.)
more in their favor. However, the information on Canadian models was not biased in this manner. The agreement that formed RCA suggested that sixty percent of manufacturing would be contributed by General Electric and forty percent by Westinghouse. Counting just the number of models, the distribution is 68 percent from General Electric and 32 percent from Westinghouse.

Douglas (1991, p. 54) presented a table of sales volumes from RCA in the interval from 1925 to 1929. The early years are omitted. It would be possible to combine our results with that source to see if the 60 - 40 allocation between General Electric and Westinghouse continued to be observed. In fact most of the Westinghouse models in Table 2 occur before 1925. This suggests that either Westinghouse was excluded from manufacturing for RCA as the years went by, or else our crediting of manufacturing to Westinghouse is seriously understated.

Conclusions

We identified from several sources, indications that in the 1920s Radiolas were manufactured for RCA by one but not both of its broadcast receiver subsidiaries. We also identified instances where receiver models were evidently manufactured by both of the subsidiaries. Overall though, receivers with single source origins appear to greatly outnumber receivers with dual sources, the stated goal of RCA after its initial two or three years of operation. Engineering difficulties and residual competitive attitudes of the two companies would likely have been the reasons preventing the full implementation of this goal.

We were limited in this line of inquiry of course by the eighty years of elapsed time, and also by the fact that we did not find equivalent information from both of the RCA member companies concerned. In the case of General Electric we found relatively detailed archives of receiver manufacturing in the Schenectady Museum. I was fortunate to have located a dedicated archivist in the person of Dr. John Anderson, himself formerly of General Electric.

In the case of Westinghouse we found much less information. The prominent Westinghouse archivists in the A.W.A., Lauren Peckham and Bruce Roloson, found that their records emphasized vacuum tube developments almost exclusively. There does not appear to be an archive of Westinghouse manufacturing that is held today by a public
museum or library. Unfortunately, too often corporations have a tendency to discard records that are more than a few years old.

Direct reference to broadcast receiver manufacturing by General Electric and Westinghouse can be found for the first few years of RCA in Archer (1939). Beyond the first few years, this topic has never seemed to catch the attention of historians. It must be regarded as something of a mystery and at the same time unfortunate that the small and struggling manufacturing companies appeal more strongly to the imagination of radio historians than do the relative giants. As a consequence we are left with gaps in the historical record about which we know relatively little. The above account is an attempt to rectify one small part of that missing history.

**Bibliography**


About the Author

Bob Murray began collecting radios about 25 years ago, and gradually came to emphasize Canadian radios of the 1920s. In 2001 he donated the Canadian part of his collection to Canada's National Science and Technology Museum in Ottawa, Ontario. Bob has written on Canadian radio history for The AWA Review, the Old Timer's Bulletin, (twice winning the Bruce Kelley Award) Antique Radio Classified, the ARCA Gazette, and other radio publications. Dr. Murray retired at the end of 2003 as Professor, Community Health Sciences (public health) at the University of Manitoba, and as Director of Research at the main university teaching hospital.
The Evolution of the National HRO and Its Contribution to Winning World War II

By Barry Williams, KD5VC

© 2004 Barry Williams

Introduction

The National HRO in its many versions (Table 1) is extremely popular with collectors of communications receivers. Because of its unique design features and its critical role in helping the Allies win World War II, it deserves a special place in radio history. Much has been written about the history of the National Company and its memorable receivers. John Nagle's article about the history of National in Volume 1 of the *A.W.A. Review* (p. 65) and Lawrence Ware's article about National's coil-catacomb receivers in Volume 11 (p. 166) are two good examples. The A.W.A. *Old Timer's Bulletin*, and *QST* and other ham publications have also featured articles about National receivers from time to time, with the HRO series being a particularly popular topic. This article documents the evolution of this memorable receiver and should help collectors identify the subtle variations among the many different models.

At the time of the HRO's announcement in 1934 National already offered the AGS and AGSX (Fig. 1), and the reduced cost Model FB-7. (The AGSX is the AGS with a crystal filer.) The AGS was probably the world's best high performance short-wave superheterodyne at that time. Hammarlund, the other radio manufacturer involved in high performance superheterodynes offered the Comet Pro. The FB-7 and Comet Pro did not have an RF amplifier or pre-selection stage, although external pre-selectors were available. A few years after the introduction of the HRO, Hammarlund introduced the Super Pro, another long-lived design quite competitive with the HRO.

The National Company's AGS was developed jointly by government and National engineers. Operating one of these receivers next to an HRO shows that the AGS has several shortcomings that were
Table 1. HRO Models (and approximate year of introduction)

<table>
<thead>
<tr>
<th>Table Models</th>
<th>Rack Model Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRO - 1st (Announced 1934, shipped 1935)</td>
<td>HRO Senior - R 1st</td>
</tr>
<tr>
<td>HRO Senior - 2nd (1935)</td>
<td>HRO Senior - R 2nd</td>
</tr>
<tr>
<td>HRO Junior - 2nd (1936)</td>
<td></td>
</tr>
<tr>
<td>HRO Senior - 3rd (1936)</td>
<td>HRO Senior - R 3rd</td>
</tr>
<tr>
<td>HRO Junior - 3rd (1936)</td>
<td>HRO Junior - R 3rd</td>
</tr>
<tr>
<td>HRO Senior - 4th (1938)</td>
<td>HRO Senior - R 4th</td>
</tr>
<tr>
<td>HRO Junior 4th (1938)</td>
<td></td>
</tr>
<tr>
<td>HRO-M (1944)</td>
<td>HRO-MRR</td>
</tr>
<tr>
<td>HRO-M Junior (1944)</td>
<td>HRO-MRR Junior</td>
</tr>
<tr>
<td>HRO-MXTM (WW II era)</td>
<td>HRO-MX</td>
</tr>
<tr>
<td>RAS</td>
<td></td>
</tr>
<tr>
<td>RAW</td>
<td></td>
</tr>
<tr>
<td>RBJ (Could be table model also)</td>
<td></td>
</tr>
<tr>
<td>HRO-W (1944)</td>
<td></td>
</tr>
<tr>
<td>HRO-5T (1944)</td>
<td>HRO-5R</td>
</tr>
<tr>
<td>HRO-5TA (1945)</td>
<td>HRO-5RA</td>
</tr>
<tr>
<td>HRO-5TA-1 (1946)</td>
<td>HRO-5RA-1</td>
</tr>
<tr>
<td>HRO-7T (1947)</td>
<td>HRO-7R</td>
</tr>
<tr>
<td>HRO-50T (1949)</td>
<td>HRO-50R</td>
</tr>
<tr>
<td>HRO-50T-1 (1951)</td>
<td>HRO-50R-1</td>
</tr>
<tr>
<td>HRO-60T (1952)</td>
<td>HRO-60R</td>
</tr>
<tr>
<td>HRO-500/HRO-500P (1964)</td>
<td></td>
</tr>
<tr>
<td>HRO-600 (circa 1970)</td>
<td></td>
</tr>
</tbody>
</table>
corrected in the HRO. The first is the plug-in coil system. The AGS operator has to locate the matching three coils and put them individually in the receiver in the correct order. The February 1996 issue of the AWA Old Timer’s Bulletin includes a well-illustrated article by William Fizette (p. 11) on the National RH receiver, another early 1930s National design. The RH used a coil module system that improved on the design of the AGS coils, and its coils resemble the coils adopted for the HRO.

The lack of a B+ switch in the AGS means the operator has either to turn off all power to the receiver when changing bands, or change the coils with B+ applied and risk a shock. (Actually, the chance of getting a shock when changing coils was rather remote.) Under typical operating conditions of that era, the nuisance involved in switching bands was probably not serious, as rapid band changing was not a high priority for most users.

The second problem with the AGS is that its tuning system is very fast and quite touchy. The dial uses a vernier scale allowing resetting to one part in 1500. The movement of the main tuning knob required to move the dial by one step is about 0.01 inches. The dial mechanism and the use of rack and pinions to drive the three variable capacitors means that the drive mechanism has to be freshly lubricated to allow smooth movement, otherwise the tuning system moves in small steps that are difficult to control. The last major shortcoming of the AGS was that because of rapidly changing technology at the time, the AGS

Figure 1. The National AGSX,. This early 1930s receiver was the predecessor of the HRO. (Author’s collection.)
Figure 2. This is one of two ads announcing the HRO that appeared in the October 1934 issue of QST. The other ad included lengthy text describing the new receiver. Shipments of the first HRO did not occur until early in 1935.
did not remain state of the art for very long. Improved vacuum tubes and a growing interest in higher frequencies meant that the AGS needed a major electronic design update after only two years of production. It is notable that the AGS had at least four different tube line-ups during these two years.

National determined that exploiting different manufacturing techniques, state of the art electronics, and improvements in mechanical design could best be addressed by a whole new receiver rather than an update of the AGS. National did attempt to improve the AGS' coil system with a late modification called the AGU. The AGU featured three coils attached to a single plate, forcing the insertion of the matching coils together in the correct order.

The First HRO Appears

The National Company announced the original HRO in October 1934, with deliveries to be made late in 1934. (An October 1934 ad is shown in Fig. 2. Fig. 3 shows a rack mount version of an early HRO.) However, actual first shipments of the new receiver were made in March 1935. The stated reason for the late delivery was that the stability was inadequate given the precision allowed by the new dial mechanism. This was largely corrected prior to shipment of the first units.

The two groups that designed the radio worked together from opposite sides of the country. The mechanical group, at National’s
The impetus for the new design was to provide a high performance superheterodyne to meet the market niche previously filled by the AGS, as well as a new requirement from the Bureau of Aeronautical Commerce, early predecessor of the CAA and FAA. The new specifications required a single module to change coils if such coil changes were required, and improved performance at 14 MHz and beyond. The HRO added a second RF stage, grouped the coils into a single plug-in module, and did not require an engineer to align each unit. The new electrical design broke no new ground, but remained state of the art for quite a few years. The HRO's mechanical design, however, was novel and excellent. The easier assembly along with a reduced cost metal cabinet allowed the HRO to be sold at a price comparable to that of the AGS.

The name of the new receiver came from a note Millen had put on the engineering drawing—"Hell Of Rush." This model was known by the initials HOR until National decided that the mnemonic when pronounced as an acronym was not acceptable. The story was actually changed to state that the original note was "Hell of a Rush Order," so HOR became HRO. (Millen set the story straight in an interview many years later.)

The HRO offered to the public in 1935 was a high quality superheterodyne with two tuned RF circuits, tuned mixer, electron coupled oscillators for the high frequency and beat frequency, and two IF stages with six tuned circuits and a crystal filter. Its electrical design is similar to James Lamb's 1932 "Single Signal Super Heterodyne," and the crystal filter was very much like the one Lamb described in QST some time later.

The front panel controls include AF and RF gain, crystal filter selectivity and phasing, BFO, AVC on/off switch, S-meter switch, B+ switch, and the wonderful HRO micrometer dial and precision worm drive mechanism. The front panel BFO control had markings of "Off," and "0" through "10." 0 on the knob indicated a BFO frequency about 5 kHz above the IF frequency of 456 +/- 2 kHz. The IF was aligned to the actual crystal frequency, and National apparently allowed a variance of +/- 2 kHz in the crystal frequency. Zero beat was
approximately 8 on the knob, and 10 indicated a couple of kHz below the IF frequency. The BFO on-off switch was ganged with the BFO pitch control. Turning the BFO control clockwise from 0 activated the BFO, by closing the switch, operated by a pin on the BFO capacitor shaft. Each time the BFO was turned off, the operator had to reset the BFO frequency the next time it was used. A separate switch would have been preferable.

The B+ switch allowed changing the coil modules without the potential for shorting B+ to ground. In the standard HRO with AC power supply there was no fuse protection, so shorting the B+ could easily damage a resistor, choke, or power transformer. The crystal filter did not allow placing the crystal in parallel like on the AGS-X, but only in series. In production a National plug-in crystal was placed on top of the phasing unit. These crystals could easily be disassembled, and contemporary publications recommended periodic cleaning with carbon tetrachloride.

The distinctive micrometer-type main tuning dial was an epicyclic unit with an outer dial marked with 50 graduations and an inner dial marked with the numbers from 0 to 500 in steps of ten. These numbers were visible through five windows in the outer dial. The inner dial was held off center and engaged the outer dial at the bottom position with a set of gear teeth. The inside of the outer dial had matching gear teeth, but a few percent more teeth so that the inner dial moved through a full set of steps for each ten turns of the outer dial.

A micrometer dial was patented in 1934 by William Harding of London, an employee of Sperry Gyroscope Company (British patent number 22-107). His invention may have inspired National to think along the same lines because National's Graden Smith received a U.S. patent in 1936 for a micrometer dial that appears to be very similar to the Harding patent. Smith definitely contributed the precision worm gearbox and capacitor mounting assembly, a work of engineering art, and the heart of the precision attributed to the HRO.

The 20-to-1 ratio gearbox was designed by Smith to eliminate backlash. The end result of this combination is a smooth, large tuning knob with 500 widely spaced graduations, allowing resetting the tuning capacitor to within about one part in 2000 or better. This precision was not surpassed for twenty years. The operator had to convert the reading on the knob into frequency by reading a
calibration curve. The plot showing frequency vs. dial reading was affixed to the front of the coil module, but this tiny graph gave only a general indication of frequency. However, making a note that the BBC on 5975 kHz had been received at 334.5 on the dial (for example) allowed resetting to the BBC with far greater ease than any competing system. The later military versions shipped to the U.K. came either with individual calibration booklets from National, or booklets were created in the U.K. giving the dial reading for each kilohertz. These booklets were columnar, not graphic, and at least some of them had the National emblem.

National believed that a really top performing receiver had to have optimized plug-in coils and an external power supply. (Power supplies for the HROs are described in detail later in this article.) The external power supply provided filament voltage of 2.5 or 6.3 volts as well as approximately 240 volts at 70 milliamperes for B+. The radio would work well with the correct filament voltage and a B+ of 160 volts or greater. Today the old National power supplies often produce 300 volts under no load because the power supply does not have a separate bleeder. (Also, line voltages are higher today than when these supplies were manufactured.) The original "Dog House" style power supply ran very warm. It is difficult to add much bleeder current as the transformer will overheat. When the B+ is turned on there is an immediate drop in voltage caused by the internal voltage dividers. National states in several documents that if you are using B+ batteries, the B+ switch should be turned "OFF" when the receiver is not being operated. (If you turn off the filaments but leave the B+ on, you will continue to drain power from the B+ battery through these voltage-dividing strings.)

The HRO Coil System

The coil modules used in the HRO were unique. There were two frequency ranges for each unit. In one mode the coil covered a wide frequency range (General Coverage Mode). In the other mode (Bandspread Mode), serial and parallel capacitors were added to reduce the coverage to approximately the width of an amateur band. The mode was changed by moving four shorting screws from one position to the other on each of the modules. The band change module consisted of four coils. Left to right, they were: 1st RF coil, 2nd RF coil, mixer tuning coil, and high frequency oscillator coil. There were four coil modules supplied with the receiver, designated A, B, C, and
D, which covered from 1.7 MHz to 30 MHz in the general coverage mode, and in the band spread mode, the 80-, 40-, 20- and 10-meter amateur bands. These modules slid into the bottom front of the receiver where temperature variations were minimal.

Each coil cover had a molded mica-filled phenolic insulator with the trademark R-39. Apparently this material was developed in 1929, and so National initially called it R-29. Prior to the HRO’s introduction the company changed the designation so it would not be defined by the year it was introduced and in subsequent years appear to be old technology. The competing phenolic resin insulators available at that time were filled with hygroscopic material such as sawdust, cloth, or paper. This property caused the cheaper insulators' characteristics to change with changes in humidity.

Each of the R-39 insulators on the National coil had five contact points. These insulators are stamped with the coil range and the position of that coil on the module. The designators were the letter of the coil followed by its position. For example, the A3 insulator should be in the third position from the left (mixer tuning), and it should be in the A coil, which covers the 14- to 30-MHz frequency range or the 10-meter amateur band. Later the RAS coils used the designation letter and a number between 5 and 8. The RBJ and possibly the RAW used the designations 9 through 12.

The electrical contacts on the insulators made contact with matching brush blocks in the receiver when the coil module was inserted. There were matching handles on the front of the coil module and the front of the receiver to ease this operation. The front plate of the coil unit was 3/16-inch thick aluminum, finished either in black wrinkle or gray paint. On the front panel were two steel chart frames containing dial calibration charts. The graph in the left frame gave the general coverage curve showing the frequency vs. dial reading, and the right frame contained a similar curve for the bandspread mode. These scales were placed on the aluminum front plate of the coil module, then a celluloid cover was placed on top of the scales, then the steel frame was installed with four small sheet-metal screws.

Coils to supplement the standard A, B, C, and D units were available to cover the frequencies from 480 KHz to 2.0 MHz and 50 KHz to 430 KHz. These were designated as follows:
E 0.960 to 2.0 MHz
F 480 to 960 KHz
G 200 to 430 KHz
H 100 to 200 KHz
J 50 to 100 KHz

The E and F coil sets are popular today since they cover the AM broadcast band, with the E coil unit also covering the 160-meter amateur band. The lower frequency coils were primarily for special or laboratory use. These additional coils were designed only for the general coverage mode; the mode-changing screws on the standard coils were missing. The right frame, which normally contained the bandspread chart, fitted over a piece of celluloid with a roughened surface on which the names and dial readings of stations could be penciled in.

National's original documentation mentions only the A through D coils as standard, and the E and F coils as being available as options. Apparently the other coils were not available when the HRO first was marketed. The later military coils did not have the bandspread capability of the early coils made for the HRO Senior. Most of the standard military receivers ordered for use in the U.K. during World War II came with coils A through E, although to indicate that they lacked the bandspread capability they used the prefix J, so that the military coils were JA through JE. It is interesting that there is no difference between the E coil and the JE coil–some coils identified as JE coils were shipped with the postwar HRO-5TA1.

**Early Production HROs**

National used two different pre-production models for illustrations in their early advertisements. The first had the same small knobs used on the AGS, tube shields unlike those seen in later National products, and controls that reflected the AGS lineage. This model included the single gain control and the serial or parallel connection for the crystal filter. The second prototype (Fig. 4) is shown without a cover. Its front view shows a knob on the top of the BFO can, something like that used in the FB-7. In addition this model has an attachment for the cover similar to that used in the later rack models, which used a special cover with studs extending through the front panel to be secured by brass thumb nuts. The actual early production model used
Figure 4. February 1935 QST ad for the HRO. This ad appeared just before actual first units were shipped to customers.
two metal bar inserts to hold the cover in place, even on the rack models that included a full case with hinged top cover and a cover plate screwed to the bottom of the receiver.

The production HRO was available in an AC-operated model and a battery-operated version. At the time National felt that best AC performance could be achieved with 2.5-V filament tubes. Table 2 shows the tube line-ups for both models.

The class A audio output section produced a couple of watts of audio to drive the speaker.

Ceramic tube sockets were used for the high-frequency tubes, including the RF amplifiers, oscillator, and mixer, and phenolic sockets for the lower-frequency tubes, except the detector/first audio, which was also ceramic. National recommended 2.8 volts at the power supply for the 2.5-volt filaments to allow for a voltage drop of about 0.3 volts from the wiring and power cable.

**Identifying the Early HROs**

The best way to characterize the major changes and to discriminate

<table>
<thead>
<tr>
<th>Stage</th>
<th>AC Model (2.5-volt tubes)</th>
<th>Battery Model (6.3-volt tubes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st and 2nd RF</td>
<td>58</td>
<td>6D6</td>
</tr>
<tr>
<td>Oscillator</td>
<td>57</td>
<td>6C6</td>
</tr>
<tr>
<td>Mixer</td>
<td>57</td>
<td>6C6</td>
</tr>
<tr>
<td>1st and 2nd IF</td>
<td>58</td>
<td>6D6</td>
</tr>
<tr>
<td>Detector/AVC/1st Audio</td>
<td>2B7</td>
<td>6B7</td>
</tr>
<tr>
<td>BFO</td>
<td>57</td>
<td>6C6</td>
</tr>
<tr>
<td>Audio Output</td>
<td>2A5</td>
<td>42</td>
</tr>
</tbody>
</table>
among models of the commercial pre-World War II HROs is by serial number. The serial number is stamped into the chassis near the antenna connector insulator. National began production of the HRO with the serial number D1. The D was a batch designation, and the digits that followed identified the particular radio in that batch. The D series may have been only 100 units; the following series were usually about 250 units. The batch designators A, B, C, I, O, appear not to have been used, giving a total of something over 5,000 receivers. When the end of this serial range was reached, National began using the batch number as a suffix instead of a prefix. The last known of the early models is 169L.

I have divided the early HROs into four models. (Actually changes were being made gradually throughout production of the HRO. So there are many "transition" models that include some features of one model and some of the next model.) Obviously the first HRO model was the unit first put in production. The second model accumulates the changes made up to the G or H production run. The third model includes those changes adopted by the P production run, and the fourth model goes from the X production run to the end of the plug-in crystal models.

The first model HRO differs from other generally seen early HROs in several ways. The main tuning knob was polished, and the graduation dial (internal to the tuning knob) had black lettering on a bright metal background. The main tuning pointer had a red "NC" engraved on the diamond, and there was no pilot light to indicate that filament power was being supplied to the radio. The S-meter had five divisions, similar to the "R" readings used to represent signal strength in that period. The S-meter was not in circuit all the time, so a momentary contact white pushbutton was used to enable it. To take a reading, the operator would ensure that the AVC was ON, then press the button. This arrangement proved unpopular. Furthermore, the pushbuttons were electrically noisy.

The knobs on the early HRO were of the bar and skirt design, but the transition from the knob to the skirt was shorter than that used later. This model lacked an external means to disable the B+ for muting purposes when used with a transmitter. The vent openings were quite small—only four rows of ¼-inch vent holes in the rear of the cabinet. The IF coils for these receivers were housed in round shield cans, and the chassis was painted black. The first HROs were
shipped with FB-7 power supplies, labeled “National Velvet-AB Type 5897 AB. Especially designed for the FB-7 receiver.”

Speakers were not advertised at this time, but a rack-mounted speaker was sometimes sold with the early HRO. These included an open eight-inch speaker in an 8½-inch panel. There may have also been some 10½-inch panels with eight-inch speakers supplied with the AGS and possibly the first HROs. There is a picture of a rack mount first model HRO as early as the July 1935 issue of QST magazine. I also have a first model rack mount with serial number E124. The ads indicate that an engraved front plate was available that mounted over the original front panel. The actual units I have seen had a front plate that replaced the normal front panel. I believe that the first production model included serial numbers D1 through D100 and E1 through E250.

These receivers generally used fixed capacitors from an outside supplier, including sealed electrolytic, paper and wax, and mica types, but resistors manufactured by National. These resistors had white bodies with hand-lettered values. Unfortunately many of these have been replaced in the surviving receivers. Apparently the connection between the end cap and the resistance cartridge can become intermittent, and the resistance values drift with age.

The coil modules used in the first model HRO have scales with white backgrounds and black calibration numbers, grid, and curves. By the F1 series the changes to the second model were being incorporated, most notably the S-meter switch was changed from the pushbutton to a push-pull switch, and the calibration scales were being changed to white lettering over a black background. Some have suggested that this lettering change might have been triggered by glue stains showing through the light colored paper. However, I have checked quite a few early scales without finding any evidence of glue problems.

In addition to the new type of S-meter switch, the S-meter in the second model had nine divisions to mid scale. The case had much larger ventilation holes, a pilot light was added, and a terminal block was added to the rear apron to allow the removal of B+ from the receiver when transmitting. (The two screws on this block need to be jumpered for the receiver to operate.) The remainder of the receiver was like the first model, with the change to the longer transition between the bar and skirt on the knob occurring during this model run.
There were additional changes to the main tuning capacitor insulators, and some changes in component suppliers. National no longer supplied the hand-lettered resistors. These receivers include serial numbers starting with F1 and ending around P1. I observed on a rack mount HRO with the serial N31 (Fig. 5) a combination of second and third model features—a gray painted chassis with round IF cans. Apparently the change to square IF cans was made by the P series.

The HRO Junior Is Introduced

The HRO Junior was introduced in February 1936, during the production run of the second model HRO. It was a lower-cost version with the crystal filter and S-meter eliminated, and including one single coil module that worked in the general coverage mode only. When the HRO Junior was introduced, National began referring to the original HRO as the HRO Senior. One fairly sure way to determine whether a model is a Junior is that the Junior tuning capacitors had tabs on the front of the capacitor bank that could be bent to adjust the receiver to the standard coil. These are visible when looking down just behind the front panel. (Fig. 6 shows an early Junior without the tabs.)

The third model of the HRO (Senior) introduced the lighted S-meter, the chassis was painted gray instead of the original black, and the IF coil shields were square. There were additional changes in the tuning capacitor insulators, and cooling vents on the cabinet ends were added. The serial numbers for these radios range from P1 to W250. A fourth model Junior is shown in Fig. 7 and an interior view of a third model is shown in Fig. 8.

Figure 5. This rack model, serial number N31, represents a transition from the 2nd type to the 3rd type. (Author’s collection.)
The primary change in the fourth model was the inclusion of the ID tag on the front panel. The insulators on the main tuning capacitor reached their final form in this model, and on most HROs of this era, a plain rectangular knob replaced the round selectivity knob. Serial

Figure 6. Early HRO Junior, without the tabs on the capacitor. (Author’s collection.)

Figure 7. HRO Junior of the fourth type. (Author’s collection.)
numbers for the fourth model extend from X1 to the end of production.

As noted above, there are several prototypes for which photos exist that were quite different from any production models. Also, National advertised at least one variation that was never produced—the HRO with internal power supply.

Rack mount versions of the later receivers were available at a slightly higher cost (about $20 more). The rack-mounted receivers were very similar to the table model HROs. The top cover of the cabinet in the rack models did not have the raised spot in the middle to allow raising the lid without damaging a fingernail because it would have interfered with sliding the unit into the rack. The front panel of the rack models was 3/16-inch thick aluminum plate with engraving to indicate the function of the B+ and AVC switches, "Selectivity" engraved above that control, and engraved pointers for the other controls. The finish on the rack panels was an alligator texture instead of the wrinkle finish used on the table models. A
gray version of the rack mount system was available in the later models.

The additional equipment advertised along with the early HROs included the HRO-P panel mentioned above for rack mounting, the RFSH speaker and panel, the RR relay rack, the LRR table mount light rack, and the E and F coils. A slightly later version of the rack mount speaker is shown in Fig. 9.

Shortly after these products appeared, a rack mount coil holder panel became available. The early coil holders were available in two sizes, one that held five coils and one that held ten coils. The ten-coil version (Fig. 10) is extremely rare, and may have been available only by special order. The five-coil version had a simple round knob, whereas the ten-coil version had a lock as seen on the later military coil holders, such as the RAS coil holder and on the SPC, described below.

In December 1936 the SPC system (Fig. 11)

![Figure 9. Later version of the rack mount speaker for the HRO. (Author’s collection.)](image)

![Figure 10. Interior view of the rare ten-coil coil holder. (Author’s collection)](image)
was first advertised. (Most likely SPC was an abbreviation for Speaker/Power Supply/Coil). It reduced the rack height of the HRO rack mount system by several inches as compared to the separate coil holder, power supply, and speaker. The original SPC advertisements showed a speaker without a grille, a simple non-locking knob for the five-coil holder, and a power supply. Later SPCs included a speaker with grille and National cloisonné emblem, a rack to hold five coils with a lock mechanism, and a power supply mounted on the coil rack and behind the speaker. The National advertisements also indicated that the original power supply, coil holder, and power supply separates were still available. A stand-alone eight-inch table model speaker (Fig. 12.) similar to the one in the SPC could also be purchased during this era.

The third model rack mount HRO appears just like the second from the outside. A quick look inside will show that the round IF cans and black chassis have given way to the square IF cans and gray chassis. The fourth model is very difficult to differentiate, other than having the HRO tag. The best way to identify it is by the serial number.

Returning to the HRO Junior, the wider selectivity of the Junior
model, lacking the crystal filter, was actually almost required by the faster tuning of the general coverage only coil. These receivers actually work quite well. Most HRO Junior users apparently bought the A and C coils sets—the A module for 20 and 10 meters, and the C module for 80 and 40 meters. These coils were not precisely tuned to the receiver with which they were shipped. Instead, they were calibrated to a standard receiver. The front of the coil for the Junior has only a single frame located in the middle of the front plate. It contains the curve for the general coverage position of the coil in use. These coils do not include the shorting screws, but do share the 3/16-inch aluminum front used on the original HRO coils. The first Junior of which I am aware has serial number L63.

The third model Junior has the gray chassis and square IF shield cans. Otherwise it is similar to the second model, maintaining the tabs in front of the tuning capacitors.

There may have been some fourth model Juniors built prior to World War II. It would be difficult to determine which units are of this type except by looking at serial numbers. By this time military personnel, primarily the U.S. Navy, Coast Guard, and Great Britain's forces, had assessed the HRO, found it met their needs well, and so the major thrust for National was shifting to military markets.

**HROs in World War II**

There were at least a few rack mount HRO Junior type receivers
built by National. Due to the lack of information on military versions of that era, it is possible that these may primarily be military versions produced after 1941, but there is at least one rack mount Junior-type receiver that was made for American Airlines. I know of HRO Juniors in both rack and table mount types, with tags that identify them as HRO-M.

In the late 1940s National made an offer to realign and add an S-meter to the receivers of those who owned units without them. The cost was low (about $10), so many of the HRO Juniors we see today have postwar factory-installed S-meters.

National's military receivers were listed in one of the company's full-page ads in February 1946. These include the HRO-M, and HRO-MX. These HROs apparently had glass tubes and used an IF frequency of 456 kHz. National also mentions the HRO-5 and HRO-W as having metal tubes and using the 456 kilohertz IF frequency. The company also stated that three receivers similar to the HRO were built strictly to U.S. Navy requirements: the types RBJ, RAW, and RAS. All had glass tubes, with the RAS using an IF frequency of 175 kHz, and the other two, 456 kHz. These receivers are described later in the article.

By September 1939 Great Britain and France were at war with Germany and Italy. Britain's intelligence establishment and their code breakers had a desperate need for high quality communications gear to intercept Axis messages. The British realized that the Marconi receivers that were available were too few in number and did not have the quality needed to serve as intercept and communications receivers. They purchased receivers from several U.S. manufacturers including RCA, National, Hallicrafters, and Hammarlund. Undoubtedly the primary British receiver for the period of the entire war was the National HRO. Approximately 10,000 HROs were used by the British in intercept operation, diplomatic communications, aboard ships, and at shore stations, as well as for clandestine use. An estimated 1,000 standard HROs were purchased by Great Britain prior to the production of the military versions.

The first military HROs were supplied to the U.S. Coast Guard and to Great Britain. The ones I have seen issued to the Coast Guard are standard HRO Seniors marked "RC-105" (Fig. 13.) The British could not buy receivers from the United States at the beginning of the war.
due to our neutrality. Many British personnel stationed in the U.S., such as those in the diplomatic service, were asked to purchase HROs from the same retail stores used by U.S. amateurs and ship them to Great Britain. In Great Britain these units were designated R-106. One of the commercial HROs found at Bletchley Park has the serial number 259J near the antenna connector. When the U.S. adopted "Cash and Carry" and later, "Lend-Lease," Great Britain contracted with National to buy large numbers of military receivers, with orders split between the HRO-M and HRO-MX (R-106), HRO-5 (R-106 Mk II) and HRO-W (R-106 Mk III). I estimate that there were probably about 3,000 HRO-Ms, about 3,500 HRO-MXs, and about 2500 HRO-5s. Very few of the HRO-Ws were delivered prior to the end of World War II.

The HRO-M was also designated in some military manuals as the HRO-MTM for table-mount, or HRO-MRR for relay rack mount. An HRO-MRR Junior is shown in Fig. 14. The M-type HROs were quite similar to the HRO Senior fourth model, but were provided with general coverage only coils. They also included special tags displaying the order number and construction information, and had a few internal modifications, such as adding transformers to eliminate the possibility of B+ on the headphones. The serial numbers on most of the HRO-M series were located behind the S-meter gain adjust resistor. The selectivity control was a rectangular knob instead of the round knob and pointer seen on some of the commercial HROs in the U.K. Serial numbers for the HRO-M appear to be similar to those on

Figure 13. Coast Guard type RC-105. (Author's collection.)
the early HROs, with a letter followed by a series of digits. These numbers are normally higher than those seen with the original HRO. Examples from Bletchley Park’s communications museum are J457, N820, and E844.

Most of the HRO-M and later military receivers were supplied with a set of four or five coils, although a minority had all nine coils. For military use, bandspread for the amateur bands was not needed, however the coils did continue to have two chart frames, one with the calibration curve, and the other with the rough surface celluloid cover to pencil in favorite frequencies. The front panel of these coils was changed from 3/16-inch aluminum to 0.093-inch steel, due to the shortage of aluminum. The rack version is very similar to the rack mount HRO Senior, but included those changes required by the purchasing entity. The plug-in IF filter crystals were last seen in these models.

A few HRO-M units have been found with crystals manufactured by Bliley. These are either replacements, or National may have purchased them to make up for an internal manufacturing shortfall. According to a statement made by National just after the war, the S-meters in these units depended on whatever National had in stock. Some of the receivers found in Great Britain have 0-1 milliampere meters, some have the standard backlit meters, most had white unlighted meters.

The HRO-MX was the next major model produced by National. It appears that the HRO-MX designation was for the rack model; the

Figure 14. HRO-MRR Junior. (Author’s collection.)
table model was designated HRO-MXTM. These units had a re-worked crystal filter, with the sealed crystal mounted inside the phasing enclosure. They are generally found with the six-volt tubes, as are the HRO-M receivers. Other than the change in the crystal filter, and the adoption of more JAN (Joint Army-Navy) parts, these are very similar to the HRO-M. The serial numbers consist again of a letter followed by one to three digits. Examples are: F42, B93, D519, and E429. It is probable that some of the HRO-MXs were Junior models, without the S-meter and crystal filter. Since the crystal filter was the primary difference between the M and MX, it is difficult to determine whether a military Junior is "descended" from the M or MX. All of the Junior styles have the tabs on the tuning capacitors.

National continued to advertise its receivers in amateur radio publications during the war years, even though they were not available for purchase by hams. Fig. 15 is an example of a National HRO ad from 1943.

The HRO-5 was the next version of the HRO produced by National. The HRO-5 used metal vacuum tubes with octal bases, with the exception of the final audio amplifier, which was a glass 6V6G. The tube complement was:

<table>
<thead>
<tr>
<th>Function</th>
<th>Tube Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st RF</td>
<td>6K7</td>
</tr>
<tr>
<td>2nd RF</td>
<td>6K7</td>
</tr>
<tr>
<td>Oscillator</td>
<td>6J7</td>
</tr>
<tr>
<td>Mixer</td>
<td>6J7</td>
</tr>
<tr>
<td>1st IF</td>
<td>6K7</td>
</tr>
<tr>
<td>2nd IF</td>
<td>6K7</td>
</tr>
<tr>
<td>Detector/first audio</td>
<td>6SQ7</td>
</tr>
<tr>
<td>BFO</td>
<td>6J7</td>
</tr>
<tr>
<td>Audio output</td>
<td>6V6G</td>
</tr>
</tbody>
</table>

These tubes are more rugged than the glass varieties used in earlier models, and external metal shields required by the glass tubes were eliminated. Often when we encounter the earlier HRO versions with glass tubes, the tube shields are missing. This may allow feedback and reduce stability.

The front panel of the HRO-5s has an added bright metal ring
around the AVC switch and the B+ switch, which is silk-screened with the switch position and use. National also introduced the flanged knob with skirt for the selectivity control, giving a more pleasant appearance. The National tags usually indicate HRO-5T for table models or HRO-5R for rack models.

The coil modules for the HRO-5 include both coils similar to those provided for the HRO-M and MX as described above, plus some coils with a silk-screened bright panel on the front of the coil with the frequency to dial-reading curve and the logging table. These are often referred to as "Silver Front Coils." As noted above, these were typically tagged as "R-106 Mark II". Those radio people in the United Kingdom who acknowledge any difference in HRO models, will usually mention the "Glass Valve HRO" and the "Metal Valve HRO."

The HRO-W was the last HRO model produced by National for military use by the U.K. These receivers were produced on contract

Figure 15. A National ad for the HRO from the ARRL 1943 Radio Amateur's Handbook.
near the end of World War II and are quite similar internally to the HRO-5T. Fig. 16 shows an HRO-W. The primary difference on the units I have seen is that the S-meters are typically the ones calibrated from 0-1 mA. These HROs came with modified rectangular power supplies, not the "dog house"-shaped supplies provided with earlier units, and were "tropicalized."

Production of the HRO-Ws began in mid-1945, and most were never shipped to the U.K. but sold to the public after the end of World War II. The dates of the application of fungicide were usually in the July to September 1945 period. After the war a National full-page technical ad in *QST* discussed the suitability of these units for radio amateurs. Most have six of the "Silver Front" coils as seen with some of the HRO-5s, and some have all nine coils. The six coils provide coverage from 480 kHz to 30 MHz, the additional coils covering 50 kHz to 430 kHz. The square power supplies are designated "697-W," and are of very high quality. The electrolytic capacitor is a plug in unit, the covers are attached with quarter-turn fasteners and they run quite a bit cooler than the doghouse supplies.

**HROs by Another Name**

There were three special versions of the HRO built for the U.S. Navy as mentioned above. National notes that while they appear similar to the HRO, they are built to Navy specifications. The most
common of these is the RAS (Figs. 17 and 18.) It was also widely used by the Marines, and in some air communication services. The Navy required that the receiver cover the frequencies between 400 and 500 kHz. The standard HRO could not, as its IF frequency was 456 kHz. To accommodate this requirement, the IF was changed to 175 kHz, allowing full coverage from about 200 kHz to 30 MHz.

The Navy decided that a crystal filter and S-meter were of limited utility in a monitor receiver likely to be exposed to vibration, so they had them removed, making the RAS more like the HRO Junior. The low frequency IF would have given higher selectivity than required by the Navy, so a 1-megohm swamping resistor was added to the secondary of the IF filters, and the secondary of the transformer was tapped down. The Navy also required the addition of a headphone coupling transformer, and that the coils be held in place in the receiver by a locking system.

The Navy further required that the extra coils be held in the coil holder so that the front panel of the coil was visible to the operator. Accordingly, the RAS coil holder was much taller than the standard coil holders produced by National. The RAS came with seven coils that are not interchangeable with the HRO coils. They are differentiated from the standard coils by the two metal plates on the front that are engaged with the locking system, and by the stampings on the coil insulators. As described above, the standard coil insulators were stamped with the coil designator and the position of the coil in

![Figure 17. Front view of the RAS. This model has the coil module locks. (Author’s collection.)](image-url)
the pack. On the RAS, the left-most coil is designated 5, and the right-most, 8. Therefore, the highest frequency coil pack that covered 14 to 30 MHz would have stampings as follows: A5, left-most 1st RF; A6, 2nd RF; A7, mixer; and, A8, right-most HF oscillator.

It is possible to retune the higher frequency RAS coils to work in the HRO since the difference in the high frequency oscillator frequency (279 kHz) is small compared to the actual frequency (from 14 to 30 MHz on the highest frequency coil). These receivers were used to monitor the 500-kHz emergency frequency in Coast Guard stations until well into the 1970s.

One option for the RAS was a noise limiter, which replaced one of the IF amplifier tubes. It is bolted in place and appears to be wired into the circuit (Fig. 19), so it is not a plug-in option, but rather was likely installed at a service depot. These noise blankers were built by Mission Bell Radio Manufacturing Co., Inc., and are designated CKB50142.

The standard setup of the RAS system required a 31-inch rack and consisted of the receiver, a power supply, the coil holder, and a speaker. The major difference in the circuitry of the RAS was that a 6F8 dual triode was used as the second detector and AGC amplifier. This replaced the dual diode/triode or dual diode/pentode found in the HRO. Due to the change in AF gain caused by elimination of the first
audio amplifier, and substitution of the triode detector for the diode
detector, the final audio tube was changed to the 6V6G, which, like
the 6F8, used an octal socket.

The second Navy model was the RBJ, also produced during World
War II. These appear to be quite rare. It is similar to the RAS, but uses
the standard 456 kHz IF. Since the standard HRO had nine available
coils, the RBJ versions were stamped as 00, 0, and 1 through 7, with

Figure 19. The add-on noise limiter chassis described in the text included two tubes, a 6H6 and a 6J5.

Figure 20. Coils for the RBJ receiver. (Author’s collection.)
the 00 coil covering 50 to 100 kHz and the 0 coil covering 100 to 200 kHz. RBJ coils are shown in Figs. 20 and 21. This receiver is said to have the same tube line-up as the HRO, and does have the coil locking mechanisms as used on the RAS.

The last variant for the Navy was the RAW. It used the 456 kHz IF and glass tubes. The only information I can find indicates that it is the same as the RBJ. If there are differences, they must be minor. RAWs must also be quite rare.

Other Modifications of the HRO

One very rare HRO variant was produced as a panoramic receiver for signals intelligence. This system used plug in coils like the HRO, but the characteristic tuning knob was gone. In its place was a motor used to rotate the special tuning capacitor through its full range and back. The output was fed to a panoramic display. This unit also had a built-in power supply.

In addition, the British modified the HRO-M and HRO-MX to better

Figure 21. This close-up of the RBJ 00 coil insulators shows how a typical HRO coil module was constructed. (Author’s collection.)
suit the requirement for a direction-finding receiver. These units had a panel over the normal antenna inputs to accept inputs from a direction-finding antenna (usually the Babcock type), and a sense antenna. Some of these models had a front panel switch to allow standard, DF and sense antenna switching. The coils for these receivers were not intended to be usable in the standard HRO, probably because they were modified for a low-impedance antenna input.

The R-140 was developed for the Signal Corps by modifying the HRO-M, MX, and the HRO-5 for use in a frequency measuring system. The modifications included removing the B+ from the speaker terminals, and allowing an audio signal to be introduced to the second detector plate. To remove the B+ from the speaker terminals, a resistor was placed between the lines normally located on the speaker terminals, one of the speaker terminals was grounded, and the other connected to the audio amplifier plate by a 0.1 μF capacitor. To provide a signal to the detector, the leads to the B+ terminals on the rear of the receiver were removed and tied together. One of these terminals was connected to ground and the other to the plate of the detector.

**HROs During the 1945-1949 Era**

National's HRO-5A was produced after the end of World War II, supposedly shipping in January 1946. This was the original HRO-5 receiver supplied with amateur bandspread coils. Some of the first versions came with the four standard HRO Senior coils covering the frequency range from 1.8 to 30 MHz. Very shortly after this receiver was introduced to the civilian market National began producing the HRO-5A-1, marked HRO-5TA-1 for the table unit and HRO-5RA-1 for the rack mount unit. This receiver included a noise limiter, adding 6H6 and 6J5 metal tubes to the tube lineup, but was otherwise very much like the HRO-5A.

There were actually three versions of the HRO-5TA-1. The first used the round S-meter seen on all the earlier HROs, and used the earlier crystal filter unit introduced on the HRO-MX. The early HRO-5TA-1 crystal filter had two variable capacitors—one for the phasing and one for the bandwidth. The bandwidth control was on the top right corner, and the phasing control directly below it. This version has been seen with four standard HRO Senior coils, but more
often with the later "Silver Front" coils that have the bandspread capability added. These coils had the standard and bandspread frequency curves on the bright metal plate. Additional coils were available as options.

The second version used a new crystal filter unit with a five-position selectivity switch that eliminated the variable capacitor and instead switched fixed capacitors into the circuit. The phasing control was moved to the upper right corner with the selectivity switch directly under it. The late HRO-5TA-1 used a different marking system and serial number series. These serial numbers were impressed into the chassis on the right side of the chassis top, opposite the antenna connectors. The chassis on the earlier models were painted gray, in the later models they are bright metal.

The third version of the HRO-5TA-1 was actually an HRO-W modified at National by adding a sub-chassis under the S-meter, which included the noise limiter and the provision of a different S-meter in place of the 0 – 1 mA unit. From the advertisements it appears that the early version came out in 1945, with the modified HRO-W produced in late 1945 or early 1946, and the square S-meter version being introduced in mid-1946.

These three versions differ very little in outward appearance. An early model 5TA-1 is shown in Fig. 22, and a late model 5TA-1 in Fig. 23.

![Figure 22. Early HRO-5TA-1. (Author’s collection.)](image)
The HRO-C in Fig. 24 is a combination of the 5RA-1 and the SPC.

Some information indicates that National produced an HRO-6 receiver, similar to the HRO-5A-1 but with a different limiter circuit.

The HRO-7 (Figs. 25 and 26) was the first departure in styling from the black wrinkle finished rectangular box HRO that had been in production with minor changes for more than ten years. This HRO was built in a gray enclosure with rounded corners. I have seen a couple of HRO-7s with a dark blue finish, but I have been unable to determine whether that finish was available.

**Figure 23.** Late model HRO-5TA-1. It has the more modern S-meter. (Author's collection.)

**Figure 24.** The HRO-5C, a combination of the HRO-5RA-1 and the SPC. (Author’s collection.)
from the factory, or if these sets were repainted professionally. The ones I have seen have matching blue coils, speakers, and power supplies.

In the HRO-7 the main tuning knob was changed from black to a matched gray knob with an inserted bright ring. The new circuit incorporated a voltage regulator and a triode high frequency oscillator. The location of the noise amplifier and the first audio amplifier were switched. The front of the coils now had a slide-rule-
type scale, spreading the frequency curve over a large portion of the coil front. The handles were gone from the front panel and the coil, replaced by two coil locks that eased the insertion and removal of the coil pack.

National introduced the Select-O-Ject, basically a high-performance audio filter, at about this time. The HRO-7 had a plug-in socket for the accessory. Another accessory, actually a complete receiver, was added to the product line at this time. The HFS receiver could be used as a stand-alone super-regenerative receiver from 27 MHz to 250 MHz, or it could be used as a converter to 10.7 MHz. For the amateur interested in VHF and UHF, the HFS used as a converter in front of an HRO was a very good choice.

The original 1930s HROs used an electron-coupled high frequency oscillator. If carefully designed this type of oscillator is relatively insensitive to voltage variations and load variations. Nevertheless, to improve the performance of the oscillator section in the HRO-7, National used a voltage regulator tube to reduce voltage variations and hence drift. Also, the triode oscillator was fitted with a frequency compensating capacitor. Many of the early HRO-7s were built on the HRO-5A-1 chassis. The factory simply riveted a plate over the chassis hole for the oscillator tube and put the miniature socket on the new plate. An original factory modified oscillator section should have the tube types stamped adjacent to the tube sockets and should be riveted. The new miniature tubes were a 0A2 VR tube and a 6C4 oscillator.

As shown on the preceding page, the HRO-7 was available in either table or rack mount versions. The rack mount version (HRO-7R) still had the 3/16-inch thick aluminum front panel and was finished in black wrinkle paint. The matching speakers for the table model were usually eight-inch diameter speakers and included a newly designed cabinet and a five-pin speaker plug. This plug change eliminated a problem with earlier HROs, namely, damaging the audio output tube by removing its plate voltage while leaving the screen voltage on the tube. Many people don't realize that when running the earlier HROs without a speaker the audio output tube should either be removed or the output terminals should be jumpered.

A new coil module (designated the AC coil) became available about this time to allow bandspread-only coverage of the new 15-meter amateur band. National also produced these coils for earlier receivers, for example the HRO-5A-1. Versions for the earlier receivers
included the handles, but used the new front scales. Additional coils offered by National at the time included the AA coil, which covered the 27 to 30 MHz range, and the AB coil, which covered from 27 to 35 MHz. The HRO-7 was the first National HRO to allow reception of narrow-band FM signals by the addition of the NFM-07 adapter instead of tuning the signal off frequency and using slope detection. The HRO-7 had an external audio input and an optional tilt base.

National appears to have printed manuals for a model HRO-12S, but it is not clear how many (if any) actual such receivers were made. This model appears to be similar to the circuit used in the RAS, including the 175-kHz IF frequency and no crystal filter. It did have an S-meter and came with a 12-volt DC power supply. It should have come with A, B, C, D and G (230 to 515 kHz) coils. It was also supplied with a speaker and shock mounts. This may have been intended to replace the RAS units that were in use well after this time. If they were made, they were most likely sold primarily to Canada.

**The HRO-50 and HRO-60**

The HRO-50 followed the HRO-7, around 1949. This model added an internal power supply and added push-pull audio output. It came with four coils—the AA, bandspread coil for 11 and 10 meters (27 to 30 MHz), along with the standard B, C, and D coils. This HRO could be used as a phonograph amplifier, and the available ten-inch table mount speaker and five or six watts of clean audio from the two 6V6Gs sounded rather good. The primary change in this model was the addition of a direct-reading frequency scale. All earlier HROs had required that the operator read the setting of the dial and look at a curve to estimate the frequency. With the earlier system, estimating the frequency to within 25 kHz was not really possible on some frequencies. Now the extra step of reading the dial and then converting by use of the frequency curve was eliminated.

The HRO-50 used the same IF system used in the HRO-5 and HRO-7. The tubes in the HRO-50 front end were miniatures. The original 6D6s, or 6K7s, were replaced with 6BA6s, and the mixer was changed to a 6BE6. Other minor changes were made, and sockets were added for a crystal calibrator and narrow band FM adapter. At the end of the run, the AA coil was replaced by the A coil.

By mid-1951 the HRO-50-1 (Fig. 27) replaced the HRO-50. It carried the conversion to modern tubes a bit further, replacing the
BFO and IF amplifier tubes with more modern versions. The more important change was in the IF circuit. It now included dual-tuned transformers, giving greatly improved skirt selectivity, and three stages of IF amplification employing 6SG7 tubes. The twelve tuned circuits gave a pass band acceptable for SSB, although the detector and AVC required special procedures for listening to SSB. The HRO-50-1 was also available in two models: rack mount (the HRO-50R-1), and standard table-top unit (the HRO-50T-1). The rack version was the last of the black wrinkle-finished HROs. A few HRO-50R-1s were made with gray finish. The military version of the HRO-50R-1 was called the R-460/UR.

While the HRO was an expensive receiver, amateur radios operators did buy quite a few of them, and those who did tended to be enthusiastic about their performance. Fig. 28 is a National ad from the 1951 ARRL Radio Amateur’s Handbook.

The coils available for the HRO-50 (Fig. 29) and later HRO-60 included the four standard ones—the A, B, C, and D coils—plus the following additional coil sets:

- AA (27 to 30 MHz)
- AB (27 to 35 MHz)
- AC (15-meter ham band)
Figure 28. HRO-50 ad from the 1951 ARRL Radio Amateur’s Handbook.
AD (6-meter ham band)
E (upper AM broadcast band and the 160-meter ham band)
F (lower AM broadcast band)
G, H, and J (50 kHz to 460 kHz)

The AD coil for the HRO-50 is very rare and may have been a special order only. Available accessories include the NBFM adapter, a crystal marker with output at 100 kHz and 1.00 MHz, the Select-O-Ject, an external DC power supply for six-volt input, an eight-inch rack mount speaker, a combination rack mount speaker and coil holder, and eight-inch and ten-inch table speakers.

One interesting note on the crystal marker oscillator was that the 100-Hz output could be adjusted to WWV, whereas the 1.00 MHz. output was not adjustable. The speaker for the HRO-50 was the same as that used for the NC-173. There were National advertisements that stated that the company was willing to build coils to cover any frequency as long as the requirement was large enough to justify the run.

Fig. 30 shows an interior view of the HRO-50R-1. Like other HROs, this model employed rugged mechanical construction and careful shielding.

In 1952 National introduced the HRO-60 (Fig. 31), the last of the vacuum tube-equipped HROs. The HRO-60 was basically the same as the HRO-50-1 with one exception—dual conversion above 7 MHz. Accordingly, the coils for frequencies above 7 MHz. (A, B, AA, AB,
AC, and AD) were not interchangeable with the earlier coils. The HRO-60 coils cannot be used in earlier receivers, but it is possible to use HRO-50 coils in the HRO-60 by bypassing the first converter. In the HRO-60 regulated current was supplied to the high frequency oscillator and mixer filaments. The 4H-4C filament current regulator tube is now quite rare, and many owners are using the 6V6 indicated in a National Service Bulletin as a substitute.

The rack mount version of the HRO-60, the HRO-60R, came with a front panel painted the same gray as the tabletop model. Accessories for the HRO-60 were the same as those for the HRO-50. The HRO-60 remained in production until 1964 as National's top-of-the-line receiver.

The HRO Goes Solid-State

The vacuum tube HRO-60 was replaced by the solid-state HRO-500, available either in a portable version designated the HRO-500P, with a case, internal speaker and rechargeable Ni-Cad batteries, or in a
table model. A rack mount adapter was also available for the HRO-500. This new receiver covered from 0 to 30 MHz without plug-in coils, and with constant 1-kHz. divisions on the familiar micrometer dial. It used a phase locked loop, locked to the harmonics of a crystal oscillator, and a linear VFO that covered 500 kHz. National wrote several one-page QST advertisements in 1964 describing the operation of the new phase locked loop. The HRO dial included an internal reduction system allowing either fast tuning (10 turns for 500 kHz) or, using an added vernier knob on the main tuning knob, about 30 turns for the full range of the VFO. Some of the main tuning knobs have a spinner attached and some do not.

Figure 31. The HRO-60, introduced in 1952, was the last of the vacuum tube HROs. A full set of coils for an HRO takes up a lot of space, as this photo shows. (Author’s collection.)
Selectivity for the HRO-500 operating at the new 262-KHz IF frequency was provided by cup core coils variable from 500 Hz to 6 kHz in bandwidth. This receiver caused quite a sensation when it was introduced and it is still popular today, though the number produced was not very great due to its high cost. Many HRO-500s were used by communications companies. For example, Tropical Radio and Telegraph had several of these at each operating position. For very low frequency use National produced the LF-10 which included a VLF tuner and amplifier as well as a provision for adding an audio filter.

The HRO-500 (Fig. 32) was almost as large as the original HRO, and its weight of 26 pounds was not far away from that of the original. The semiconductors used were a combination of germanium and silicon transistors. Performance, compared to modern solid-state receivers, was fairly poor, especially in strong signal conditions, but compared to other receivers of similar vintage, it performs quite well. The frequency read-out, pre-selector, and stability were very good.

The HRO-600 was the last of the HROs produced by National. I will not comment on it here because I have not had the opportunity to

Figure 32. The solid-state HRO-500. (Author’s collection)
study one. These fully transistorized receivers are extremely rare today.

The HRO and its Special Role in Signals Intercept During World War II

The HRO had a long and illustrious career, with the greatest amount of use in World War II occurring in Great Britain. The estimate most normally quoted in references to signals intelligence during World War II was that effective signals intelligence and cryptanalysis shortened World War II by approximately two years. The scholarly book *Action This Day* acknowledges that without the availability of the excellent American receivers, primarily the HRO, the cryptanalysts and traffic analysts would have not been able to provide this intelligence.

Two books on this topic that I recommend highly are *England Needs You* by Joan Nichols, and *The Secret Wireless War* by Geoffrey Pidgeon. Nichols, a young lady who became an intercept operator at Beaumanor during World War II, includes a lot of information concerning the daily life of the operators, along with the problems they faced. Pidgeon describes in detail the equipment used for communication with the clandestine agents, at the intercept stations, and for distribution of the Enigma intelligence. Both books reference David White, the curator for the diplomatic wireless station and "Y" station at Bletchley Park (Figs. 33 and 34). David has been kind enough to provide a large amount of information to me concerning the HRO at war. He worked for the Diplomatic Wireless Service after World War II until his retirement in 1992. HROs continued in operation in the Diplomatic Wireless Service until 1957, and at some of the embassies until 1959. They were replaced by Eddystone 730 receivers, which the operators thought were inferior to the HROs.

Bletchley has a collection of twenty or so HROs, of which David keeps a dozen or so fully operational. Normally there are five or six HROs in the Diplomatic Wireless Hut and six more in the "Y" station. Most of the HROs used in Great Britain did not come with National power supplies or speakers. These were provided by local builders in the United Kingdom. The speakers are simple metal enclosures with perforated front grille. The power supplies built in the U.K. by two different companies were much more substantial than the "Doghouse" supplies normally seen with HROs in the U.S. These power supplies
are marked G5NI, Birmingham, and PSEI Limited. With the limited shipping space available during the war years and the requirement for 240-volt "mains" power, the local construction of these accessories was a very good option.

Early in the war the government of Great Britain recruited many of the Britain's licensed amateurs to listen for clandestine transmissions from inside the country. These were called Voluntary Interceptors or VI. Later in 1939 they were recognized as the Radio Security Service, or RSS. The VI and RSS operator had to make do with what was available until the HROs arrived in large enough quantities for this vital work. After the war these surplus receivers were sold to the VI/RSS operators for 5£ each. Some VI operators recalled using two-tube regenerative receivers until being issued an HRO. Apparently many of the HROs purchased for the VI/RSS operators were commercial units with nine coils including the standard bandspread coils.

Figure 33. David White, Curator of the communications aspects of Bletchley Park, along with vintage equipment on display. If you visit this site, do try to meet David. (Photo from David White.)
The largest use of receivers in Great Britain during World War II was by the intercept stations that monitored German and Italian traffic outside Great Britain. There were a few intercept stations that used the Marconi and Eddystone receivers, but most used HROs. Examples include the Navy stations at Scarborough, which used 80 HROs, and Flowerdown, with 40. Hanslope used 66 HROs in 32 listening positions, 30 having two HROs each, and two positions having three HROs each. Other stations and the numbers of HROs at each were:

<table>
<thead>
<tr>
<th>Station</th>
<th>HROs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forfar</td>
<td>60</td>
</tr>
<tr>
<td>Gilnahirk</td>
<td>12</td>
</tr>
<tr>
<td>Nash</td>
<td>8</td>
</tr>
<tr>
<td>St. Erth</td>
<td>12</td>
</tr>
<tr>
<td>Thurso</td>
<td>14</td>
</tr>
<tr>
<td>Weald</td>
<td>8</td>
</tr>
<tr>
<td>Whaddon</td>
<td>30</td>
</tr>
</tbody>
</table>

To eliminate power line noise, Nash and Weald used DC power supplies for the receivers and had diesel generators to charge the
batteries. The other stations used "mains" power. There were some listening operations in India, Ceylon, and Australia during WW II; some used HROs and some used the RCA AR-88. The first listening station at Bletchley (Station X) used a pair of RCA AR-77s. One of the original receivers has been returned to the small room in the attic of the mansion.

**Working Conditions for the Intercept Operators**

While their HRO receivers were state-of-the-art for the time, intercept operators faced difficult listening conditions. The Germans transmitted noise or music very near the frequency of their code transmissions (in British jargon, "wireless telegraphy" or "W·T" transmissions) to reduce the probability of intercept outside the intended communications radius. Signals from the remote Axis forces were generally weak and drifting in frequency, and messages were normally keyed manually. Recognizing a particular operator's "fist" allowed the intercept operators to follow the transmitting stations and operators when they changed call signs and frequencies. Sometimes call signs were changed daily, and the transmitting frequencies changed even more often. Transmissions were coded groups and had to be copied perfectly. At times more than one operator would be assigned to insure perfect copy. When operators missed part of a transmission they would write in probable letters with a question mark, and make dashes to indicate the number of letters missed. Often this allowed the reconstruction of a complete transmission from the combination of two or more partial intercepts. Under these demanding conditions, the quality of the receivers used made a huge difference between success and failure.

A typical intercept station such as Beaumanor might have several receiving set huts, or "Set Rooms." A typical set room resembled a schoolroom, with the operators facing a control operator seated at the front of the room facing the operators. There would be a central aisle with operators and sets on each side of the aisle. The control operator would assign most sets to monitor particular frequencies and would connect the sets to the antennas deemed preferable for that frequency and distance.

The antennas were primarily V-beams and rhombics at heights of 50 to 75 feet. There would be multiple antennas for each band of frequencies pointed toward different locations from Africa to the
Arctic. Each antenna was fed to a wide-band amplifier that distributed the signal to as many as twenty HROs. These amplifiers were designed by the General Post Office and used type 807 vacuum tubes as class A RF amplifiers.

Once the operator was assigned a frequency by the control operator they would then use the calibration book for their receiver, or a "cheat sheet" attached to the front of the receiver and marked with something like "remove under threat of death" to tune the correct frequency. The operator might then wait for hours until some action occurred. Unless they were quite familiar with the station, the operators would have to determine whether the station was part of a network, and if so, the type of network – star or circle. In the circle network everyone transmitted on the same frequency: the star had two frequencies – one for the control station to transmit on, and one for everyone else. The star network would either require a dual receiver setup, or two operators. Operators would copy the preamble at the top of the "Red Sheet" (Fig. 35) and the coded groups below.

Figure 35. A Bletchley Park “Red Sheet,” no doubt received on an HRO. Copying code groups was tedious, yet the critical nature of the task meant the intercept operators could not allow their concentration to lapse. (Photo from David White.)
For some coded messages such as Enigma, the cryptanalysis required approximately 100 messages per day. Given the dozens of codes being used, the volume of coded messages intercepted was huge—sometimes several hundred thousand coded groups per day. Several good books concerning the breaking of the German and Italian codes are available, including Winterbotham's *The Ultra Secret*, the first book to reveal the secret of the success of cryptanalysis in Great Britain during WW II, and David Kahn's *The Codebreakers*. I recommend a visit to the Bletchley Park Internet site: www.bletchleypark.org.uk as well as Tony Sale's Codes and Ciphers internet site www.codesandciphers.org.uk. If you have an opportunity to visit the United Kingdom, it is well worth the time and the 10£ entry fee to visit Bletchley Park. Expect to spend a full Saturday or Sunday there, and you will wish for additional time.

There were thousands of W-T intercept operators in the United Kingdom during World War II. Most were young women who knew nothing about radio or W-T until after induction into their particular branch of the service. The stress on the intercept operator was severe. Missing part of a critical message could mean additional Allied casualties. At times a stressed operator might have been taken off intercept service and assigned to search operations where they would tune over a band of frequencies looking for new stations; this was thought less stressful than intercept operation. In the worst case an over-stressed operator would be reassigned to radio direction finding.

The operators mentioned a couple of problems. One was the possibility of contacting the uncovered B+ terminals on the back of the receiver. A second was that the power supplies were located on the floor, and periodically operators would accidentally kick the supplies' on-off switches and turn them off. Joan Nichols mentions that the male operators never accidentally turned off the supplies. She wondered, "what did they do with their feet?"

Having just read a description of the operating conditions you can see why the HRO was referred to as "the Remarkable HRO," "the Cadillac of Receivers", and "the Best Receiver Money Could Buy", by many of the operators quoted in *The Secret Wireless War*. The stability and excellent capability of returning to a particular frequency were better than any other receiver available in the United Kingdom until the early 1960s.

In order to distribute "Ultra" intelligence, Special Liaison Units and
Special Communication Units (SCUs) were formed. The Special Communications Units were equipped with a standard British Mark III transmitter and an HRO., (Fig. 36). These were mounted in various vehicles until the Dodge ambulance chassis (Power Wagon) was found to be the best available vehicle. The Mark III was a 2-tube crystal-controlled transmitter of about 30 watts output power. They were assigned to the various commanders, and units in the field were required to keep in contact with the home units in Great Britain in order to pass new intelligence to the commanders as quickly as possible. These very successful communications teams had to be ingenious in finding suitable locations for their wire antennas that allowed reliable communications while having to move frequently–sometimes up to three times a day.

One illustration of the skill of the SCU operators in using their transmitters and HROs occurred at the end of the war when there were several different communications systems located within one of the

Figure 36. Special Communications Units (SCUs) used this portable system, called a “coffin” set, consisting of an HRO, a Mark III transmitter, power supply, and coils. (Photo from David White.)
stadiums in Germany. The SCU offered to send messages for a General whose own communications unit had not been successful. The General visited the SCU and asked to see their equipment. When they showed him the 30-watt Mark III, he became enraged because he could not understand how they could stay in communication with England when his own unit with 500-watt transmitters could not get his messages through. Several of the SCU operators commented on the high reliability of their HROs. Some reported not having to do any maintenance—even so much as replacing a vacuum tube—during the period spent traveling through Europe between D-Day and VE-Day.

**HROs in the U.S. Military During WW II**

In the United States the HRO and its variants were also widely used during World War II, primarily by the Navy, Coast Guard and Marines. These sets include the RAS, and the "reverse Lend-Lease" version of the HRO built by Amalgamated Wireless of Australasia Ltd.—the table mount AMR-100 and the rack mount AMR-101 (Fig. 37). I have seen pictures of the control station for the Coast Watchers in the Solomon Islands (call sign KEN) prominently showing an RAS; the AMR-100 can be seen in a late 1945 QST article concerning the U.S.S. Apache, a communications ship used by McArthur in the Philippine Islands. You will also see banks of RAS receivers in pictures taken at locations such as Albro Lake, as well as other communications and training stations.

At the beginning of WW II you will find references to patriotic owners turning in their HROs for use during the period that the military demand for receivers outstripped supply. I know of several early HROs (including HRO Juniors) built in 1937 or 1938 that have military acceptance markings. We can be fairly sure that at least some of these were privately owned before finding a place to serve during the war years.

National supplied a much larger number of NC-100/NC-200 variants than HROs to the U.S. military during WWII.

**Modifications to HROs**

The wide availability of the HRO, and the fact that they were often available inexpensively as postwar war-surplus items led to these receivers being highly modified by amateur radio operators. Not many
hams thought that the HRO they picked up for a song in surplus stores in the late 1940s or early 1950s might be worth twenty times as much today as they paid for it if they had not modified it. Of course there were numerous articles in ham publications on how to improve the performance of older receivers and in those days no one worried about keeping early receivers original.

The modification most often seen on early HROs is the change of the older oscillator tube (6C6 or 6J7) to a miniature 6C4 triode oscillator, and the addition of a voltage regulator such as the 0A2—the same change National adopted with the HRO-7. The next most often seen modification is the addition of the noise blanker as adopted by National on the HRO-5A-1. Normally this modification consists of the addition of a 6H6 and a 6J5. Typically if you see a 6H6 in an HRO earlier than the 5-TA-1, then a limiter has been added. Usually there will also be an additional control between the S-meter and the main tuning dial.

The third most popular change was to replace the earlier vacuum tubes with later versions. Depending on when the modification was performed, this might be octal vacuum tubes in place of the six-pin glass tubes, or miniature vacuum tubes in place of either the octal or six-pin glass vacuum tubes. Normally the modifications will be in the RF amplifiers, mixer, and oscillator. The miniature tube modifications usually upset the gain distribution in the receiver. Today when serious

Figure 37. The AMR-101, built by Amalgamated Wireless. (Author’s collection.)
National collectors find one of these modified receivers they frequently restore it to its original circuit, in spite of the fact that the voltage regulated high frequency oscillator and noise limiters were improvements in these receivers.

If you are lucky enough to own an HRO receiver, perhaps this article will allow you to see it in a different light. It was a landmark in the development of the superhetrodyne receiver, and a great contributor to the Allied war effort during World War II. Many intercept operators will state that it was the best intercept receiver available during the war, and for quite some time after the end of the war. It was stable, rugged, simple to operate, and the dial mechanism allowed resetting to a particular frequency much better than any other available receiver.

Reverse Engineered HROs

During and after the period spanned by World War II the HRO received sincere flattery by being copied by the Germans and the Japanese. There are two German copies of the HRO, one made during the war, and one made after the war in East Germany for supply to the Chinese. The Japanese made a copy of the dial and drive mechanism, complete to the emblem on the top, and also supplied a number of receivers with a different dial mechanism, but with the general layout and plug-in coils introduced by the HRO (Fig. 38).

There were also three versions made in Allied countries, one in New Zealand, and two in Australia. Probably the best of these was the extremely well-made Amalgamated Wireless of Australia Models AMR-100 and AMR-101. The Kinglsey AR-7, also made in Australia, used a single tube for the converter stage, and would have suffered from oscillator pulling.

The Collier and Beale Model 941 SWB built in New Zealand is a very close copy of the HRO, actually using imported dial mechanisms manufactured by National. The information available on these copies indicates that the Australian versions operated very well, and the German versions met the specs of the original HRO, but were easier to overload. There is an operational Japanese HRO at Bletchley Park, but I did not have time during my visit to compare it side by side with the original HROs.
HRO Power Supplies

The evolution of power supplies for National receivers is somewhat involved. Prior to the AGS National built the SW-3, the AC version of which required 2.5 volts for the filaments of its three vacuum tubes and 180 volts at about 40 mA for B+. This was provided by the Model 5880AB power supply. National ads indicated that the 5880AB could be used with the FB-7, though it is not recommended. This power supply is really too light for the FB-7, even if the final audio amplifier tube is removed.

There were two correct power supplies for the FB-7: the 5887AB and the 5897AB. The 5887AB had outputs of 2.5 volts for the filaments of the seven-tube FB-7, along with about 180 volts of B+ at something like 60 mA. This smaller of the two supplies allowed the operation of the FB-7 at lower listening levels, where "room filling loudspeaker sound" was not required. The heavier-duty Model 5897AB provided 2.5-volt filament voltage with sufficient current to supply the nine vacuum tubes in the HRO, and provided about 240 volts of B+ at 70 mA to allow full output from the audio output tubes in either the HRO or the FB-7.

For the AGS, National supplied the Model 5886AB which was also

Figure 38. A Japanese attempt to copy the HRO. (Photo from David White.)
supplied with the National SRR receiver. This power supply (Fig. 39) provided filament voltage at 6.3 volts, adequate for nine vacuum tubes, along with 240 volts B+ at 70 mA. National also offered a single rack mount supply, Model GRSPU, available with either 2.5- or 6.3-volt filament voltage, and adequate output for several watts from the audio amplifier. These may have been designated as GRSPU-2 and GRSPU-6, although I have seen one GRSPU with 2.5-volt filament output marked only "for HRO."

The second National rack mount power supply, the Model GRDPU, was capable of providing power for two receivers. Basically it was two GRSPU internal units in a single rack panel. These dual units were available with filament voltage outputs of 2.5/2.5, 6.3/6.3, or 2.5/6.3.

By late 1940 National introduced the Model 697 power supply Figs. 40 and 41), which provided the proper current for an HRO with 6.3-volt filaments. I have seen a few rack mount power supplies marked 697. With the exception of the rack model, the power supplies mentioned above were all built into small enclosures commonly called "Doghouse" style power supplies.

Early in 1945 National produced the 697-W, a heavier duty external supply with a plug-in electrolytic capacitor. Because they were sometimes used in humid tropical climates, they were treated with fungicide between early 1945 and September 1945. National had also announced a vibrator-type external DC supply for the HRO in November 1939. It fed the battery voltage to the filaments and used a vibrator pack to provide approximately 180 volts B+ at 50 mA. The vibrator pack was normally supplied by Mallory.
National's announcement stated that these units were built to order, and not normally stocked.

The AC supplies described above employed a type 80 full-wave rectifier and a capacitor-input dual-section filter. The pi-section filter typically used a triple-section eight-μF electrolytic capacitor and a choke of approximately ten henrys. One of the electrolytics was connected across the output of the rectifier. The pulsating DC then passed through the choke, and to the other two sections of the capacitor that were connected in parallel across the output.
the output of the choke. In the 697 supply the rectifier is typically a 5Y3 although the Rider schematic (page 14-35) shows an 80. The early supplies included a pair of small RF bypass capacitors. These 697 supplies may also contain a variable resistor with the tap grounded and the two ends connected to the filament lines. The HRO moved this resistor to the receiver chassis, making it more effective, as the power supply chassis is not normally connected to the receiver chassis.

During most of the HRO years, corresponding rack mount versions of the power supplies were available. Fig. 42 is an example of an early rack mount power supply.

National published an advertisement showing the following as dates that the models listed below were first available:

- SW-3: August 1931
- AGS: July 1932
- FB-7: February 1933
- SRR: April 1933
- HRO: January 1935

In addition, the first ads for the following models appeared in QST magazine on the dates listed.

- HRO-Rack Mount: July 1935
- HRO Junior: February 1936
- SPC: December 1936

I have tried to avoid factual errors in researching and writing this article and accept responsibility for any that have crept in. Please feel

**Figure 42.** Early rack type HRO power supply. (Author’s collection.)
free to contact me concerning errors, additional facts, and particularly observations that do not agree with this article.

Acknowledgment

I want to thank a large number of people for providing information for this article. David White provided a wealth of information and guidance concerning the military use of the HRO in the United Kingdom as well as the view of an intercept and point to point W-T operator using the HRO. He not only helped me, but also was instrumental in getting Joan Nichols and Geoffrey Pidgeon to write their excellent books. I also appreciate the help of my friends at the RAF museum in Henlow, including Dave Thompson and Vic and Mike who help keep the museum in great condition. Closer to home, John Orohood, Greg Gore, Rob West, and Henry Hand at the Western Historic Radio Museum have all produced excellent information and guidance. Most of all, I must not forget my mentor on all things electronic, Max Busick (SK), W5GJ until his passing, and his son Don Busick, K5AAD, last of the line.

About the Author:

Barry Williams’ grandmother encouraged him to get an amateur radio license at an early age. When he was 11 years old, she purchased a Hallicrafters S-38E for him, which he kept until age 14, when he acquired a better-performing BC-348Q receiver. By the early 1960s, he had read everything he could about radio and had achieved 13 w.p.m. copying CW. At the time he lived in a small East Texas town and would have had to travel 130 miles to Dallas to take the FCC exam, so obtaining a ham license had to wait for a more opportune time.

After majoring in industrial engineering at Texas A&M, marrying, and getting his career in order, Barry once again turned his attention to radio and obtained an Advanced Class ham license. His call, which he has held ever since, is KD5VC. He owns modern ham gear, but still enjoys listening to old boat anchor receivers. Barry has written other articles on radio topics for publications such as QST.

Barry has had a keen interest in National HROs for quite some time. His HRO collection currently numbers about forty (including parts sets). He has researched their characteristics, has been in frequent
contact with other HRO collectors, and has even traveled to England to research the use of HROs by the British in World War II.

Barry is Manager of New Product Development at Varco Tuboscope in Houston. He and his wife have been married for 35 years, and have four children and five grandchildren. In the photo below Barry is flanked by his two oldest grandchildren, Kennedy Rose Williams on the left, and Timothy Reichert on the right.
**Cumulative Table of Contents and Author Index for Volumes 1 through 17 of The AWA Review**

(Order reprints and CDs from the AWA: http://www.antiquewireless.org)

**VOLUME 1 - 1986**

- The Founding and Development of the Antique Wireless Association and Its Museum by Charles M. Brelsford
- John Stone Stone on Nikola Tesla's Priority in Radio and Continuous-Wave Radiofrequency Apparatus by Leland I. Anderson
- Farnsworth's Contributions to Modern Electronic Television by Stephen F. Hofer
- A Radio Amateur in World War I by Clarence D. Tuska
- A Brief History Of The National Company, Inc. by John J. Nagle
- Atwater Kent Early Radio Development by Ralph O. Williams
- Field Test of the Armstrong Wide-Band Frequency Modulation System From The Empire State Building, 1934 AND 1935 by Thomas J. Buzalski
- An Interview With Paul Godley by Wayne M. Nelson, W4AA

**VOLUME 2 - 1987**

- De Forest Radio Telephone Companies, 1907-1920 by Thorn L. Mayes
- Across the Gap: an Appraisal of Spark Radiotelegraph Engineering by A.C. Goodnow
- Atwater Kent Early Radio Development - The Mahogany and Metal Boxes by Ralph O. Williams
- Hammarlund Radio by Stuart Meyer
- A Century of Telegraph Key Development by Louise Ramsey Moreau
- The Philadelphia Radio Story - The First Fifty Years by Rexford M. Matlack

203
VOLUME 3 - 1988

Guest Editorial by Donald Christiansen.................................................................5
Atwater Kent Radio Development - Part III - The A.C. Powered Receivers by Ralph 0. Williams.........................................................6
Program Transmission and the Early Radio Networks
by Ludwell A. Sibley..........................................................................................34
Audio Frequency Characteristics in Early Broadcasting
by Robert M. Morris.........................................................................................48
A.C. Supply for Radio Receivers - How the Lowell and Dunmore Patents (Almost) Changed the Industry
by Alan Douglas...............................................................................................61
The Radio Apparatus of Ernest C. Mignon
by Lauren A. Peckham......................................................................................79
Foreign and Military Telegraph Keys
by Louise R. Moreau and Murray D. Willer.....................................................98
The Alexanderson System for Electro-Mechanical Production of Radio-Frequency Energy by Glen C. Fuller............120

VOLUME 4 - 1989

A Sketch of Early Radio Vacuum-Tube Research and Development at the General Electric Company
by J.M. Anderson.................................................................................................6
The HRO Report: Dating the Early HRO by Charles P. Fisher 32
Tube Manufacturing at Western Electric: The WE 300B
by Attila R. Balaton..........................................................................................45
The Feminine Touch in Telecommunications
by Louise R. Moreau........................................................................................70
A Decade of Electroacoustic Reproduction (1920-1930)
by Floyd A. Paul...............................................................................................84
An Elusive Frame of Television History Preserved
by William E. Denk..........................................................................................99

Western Electric Tubes: Some Interesting and Historic Types by Ludwell Sibley.................................................................110
Early Microphone History by Bob Paquette.................................131

VOLUME 5 - 1990

Supplying Tubes, Sets, and People to RCA: the General Electric Connection by John M. Anderson...................................................1
America's Wireless Spies by Bart Lee................................................21
The Triode That Predated de Forest: Robert Von Lieben and the LRS Relay by Thomas H. Briggs IV....................................................45

Spies Use Radio - The Radio Intelligence Division in WW II by George E. Sterling, W1AE..........................................................63
Elements of Reference for Identifying and Dating Western Electric Electron Tubes by Attila R. Balaton.............................................109
San Francisco's Network Broadcast Centers of the 1930s by John F. Schneider, KB7AK.................................................................123
The U. S. Patents of Armstrong, Conrad, de Forest, DuMont, Farnsworth, Fessenden, Fleming, Kent, Marconi, Zworykin by David W. Kraeuter......................................................143

VOLUME 6 - 1991

The Eaton Tube Collection by George H. Clark, Bruce Kelley Lauren Peckham L. C. F. Horle, and W. A. Eaton........................................1
The General Electric Company Considers Buying the De Forest Radio Telephone and Telegraph Co., 1916 by John M. Anderson......................................................13
The First Years of Wireless in the Hawaiian Islands by Robert J. Wiepert and Tina M. Wiepert..........................................................19
A Review of Early Television in the UK by Pat Leggatt..................37
Signal Corps SCR-RC-BC Directory by Frederick W. Chesson ....49
Who Invented The Superheterodyne? by Robert Champeix, translated by Richard Foster..........................................................97
Amateur Radio in the New York City Area Pre-WW I by Daniel C. McCoy..........................................................115
Radio Tube Manufacture in Australia by Fin Stewart..................125
The Military Communications Explosion, 1914-18  
by Louise Moreau.................................................................................135

The U.S. Patents of Alexanderson, Carson, Colpitts,  
Davis, Gernsback, Hogan, Loomis, Pupin, Rider, Stone,  
and Stubblefield by David W. Kraeuter........................................155

VOLUME 7 - 1992

Ricevitore Popolare Italiano (The Italian People's Receiver)  
by Robert Lozier..................................................................................1

Memories of Early Electron-Tube Development  
by Edward W. Herold.................................................................15

The First High-Power Transmitter at Poldhu  
by Desmond Thackeray.................................................................29

Secret Tubes for Radar: The Western Electric 700-Series  
by Ludwell Sibley...............................................................................47

Appendix - Production of VT90 (710A) Valves in Australia  
by Colin MacKinnon........................................................................66

Military Electronic Equipment - Naval Equipment  
Manufacturers by Fred Chesson.......................................................69

A Brief History of the Valve Audio Amplifier  
by Carlos Fazano................................................................................91

The Eaton Tube Collection Revisited by Jerry Vanicek........107

The Arc Method of Producing Continuous Waves  
by William J. Byron, W7DHD.........................................................119

Robert H. Goddard and the Goddard Oscillator  
by M. D. Hall, K2LP.........................................................................151

The Evolution of Broadcasting from the Transmitter  
Viewpoint (Author Unknown)..........................................................159

Index and Additions to Patents Lists by David Kraeuter..........185

VOLUME 8 - 1993

Unusual Military Morse Keys by Louis Meulstee, PA0PCR........1

Rare Tubes: How to Recognize Them, and Why They  
Are Rare by Gerald F. J. Tyne..................................................47

206
A New Bibliography of Reginald A. Fessenden  
by David W. Kraeuter..............................................................55

'Federal' As a Telephone Company by Ludwell Sibley........67

The KFS-Federal-Mackay Story. From CW Arc to Silicon Valley by Hank Olson, W6GXN, and Bill Orr, W6SAI......75

Joseph T. Fetsch: Vacuum-Tube Engineer and Collector  
by Jerry Vanicek.......................................................................107

A History of the National Electrical Supply Co.  
by Edward B. Duvall, ex-3DW..................................................117

Navy Electronics Directory by Frederick W. Chesson.........123

A Glimpse at Old-Time Transmitter Development  
by Walter H. Nelson...............................................................149

VOLUME 9 - 1995

Marconi - The Man and His Apparatus  
by James H. & Felicia A. Kreuzer...........................................7

The International Contest for Radar by Ed Lyon................97

The Real Story of the Magnetron by Ed Lyon.........................181

Fritz Lowenstein - The Forgotten Man of the Vacuum Tube  
by Pat Dowd.............................................................................205

83 Years of U.S. Amateur Licensing by Neil D. Friedman......225

VOLUME 10 - 1996

Atwater Kent - Master of Marketing by Ralph 0. Williams.......7

The Race for Radiotelephone: 1900-1920 by Mike Adams........78

Commemorating the 75th Anniversary of Radio Central  
by Christopher Bacon.............................................................150

Defiance in the West - The Heintz and Kaufman Story  
by Hank Olson and Al Jones......................................................188

The Collins Radio Company - Ingredients of Success  
by F. Parker Heinemann..........................................................222

Gilfillan Bros. Inc., Early Records by Floyd Paul...............245

207
VOLUME 11 - 1998

The Technology of the E. H. Scott Radio Laboratories
by Kent A. King.................................................................6

The Beginnings of Vacuum Tube Radio at Western Electric
by Dirk J. Vermeulen...........................................................104

Trans-Pacific Radio Telephone Circuits and the A-3 Privacy
Device by Roy S. Blackshear..............................................150

The National Radio Company, Inc. - The Coil-Catacomb
Radios and Variations on a Theme by Lawrence R. Ware.........166

VOLUME 12 - 1999

The Atwater Kent Radios by Ralph O. Williams

Introduction..............................................................................7

Chapter 1. Radio Instruments and Mounting Boards...............9

Chapter 2. Amplifying Instruments........................................6

Chapter 3. From Instruments to Radios - The Pre-Ten Series......27

Chapter 4. The Model 10 Series............................................58

Chapter 5. Reproducers and Loudspeakers............................81

Chapter 6. The Twenties Series..........................................84

Chapter 7. The Thirties Series............................................102

Chapter 8. The Forties Series............................................140

Chapter 9. The Unique Model 50, No. 8500...........................156

Chapter 10. Kent's First Consoles........................................158

Chapter 11. New Concepts and the Model 55.........................161

Chapter 12. The Sixties Series............................................166

Chapter 13. The Seventies Series, the Lettered Chassis Types....173

Chapter 14. After the Tuned-Radio-Frequency Sets................178

Chapter 15. Atwater Kent's New Product Line.......................182

Chapter 16. Atwater Kent Uses Three Numbers.....................210

Chapter 17. The 1933 Series..............................................230

Chapter 18. The 1934 Series..............................................253

Chapter 19. The 1935 Series..............................................283

Chapter 20. Closing.........................................................305

Appendix

1. The Boards, Restoration.................................................312

2. Index of Models..........................................................318
3. Characteristics of Models - Insert

Author's Profile..................................................................................................................320

VOLUME 13 - 2000

Manufacture of Broadcast Receivers by the Northern Electric Company in the 1920s by Robert Murray.........................7


Marconi's Transatlantic Triumph - a Skip into History
by Bartholomew Lee...........................................................................................................81

Radio Direction Finding and "Huff-Duff"
by Richard C. Foster and Pierre Demerseman..........................................................98

"Anything You Can Think of Doing, We'd Just Do It" - The Early History of Charlotte's Radio Station WBT
by Pamela Grundy...........................................................................................................115

Early Radio Stations: Weeds and Trees
by George A. Freeman......................................................................................................124

VOLUME 14 - 2001

Spark Keys: The Interplay of Wireless History and Technology by Russ Kleinman, Jim Kreuzer, Karen Blisard, and Felicia Kreuzer..................................................................................................................7

The Spark Key Project by Russ Kleinman and Karen Blisard.............82

The First Thirty Years of the Canadian Marconi Company
by Roger Hart and Robert Murray.................................................................92

Doctor Lee De Forest, Professor Warren Johnson, and the American Wireless Telegraph Company
by Glenn Trischan.......................................................................................................150

The Bakelite Radio: An Icon of the 20th Century
by Barbara Havranek..................................................................................................178

Cumulative Table of Contents for all Volumes
of The AWA Review....................................................................................................195
VOLUME 15 - 2002

Radio Spies: Episodes in the Ether Wars by Bart Lee.................7
The Marconi Wireless Telegraph Apparatus in R.M.S. Titanic Confirmed by Observations of the Wreck
by Parks Stephenson.................................................................98
Sowing Seeds: Growing America's Broadcasting System
by George A. Freeman...............................................................126
"Just Plug-In - Then Tune In" - The First Commercial Light-Socket Operated Radio Receivers with AC Tubes
from Rogers Radio Ltd., Toronto, Canada
by Maurice Chaplin........................................................................147
Cumulative Table of Contents for all Volumes of
The Awa Review............................................................................179

VOLUME 16 - 2003

The Eminent Years of Powel Crosley Jr., His Transmitters, Receivers, Products, and Broadcast Station WLW,
1921-1940 by Charles J. Stinger..................................................7
Early Wireless Pack Sets: Spark Hits the Beach
by Russ Kleinman, Karen Blisard, Jim and Felicia Kreuzer,
and August Link............................................................................96
John F. Rider, Hugo Gernsback, and RCA Radiotron:
The Saga of Rider's Early Radio Manuals
by Charles C. Kirsten...................................................................135
The History of the Development of Radio Grille Cloth
by Barbara Havranek......................................................................180
Cumulative Table of Contents for all 16 Volumes of
The AWA Review.........................................................................206

VOLUME 17 - 2004

The Regency TR-1 Fifty Years Later by Paul R. Farmer..........1
A History of the Kodel Radio Corporation
by John E. Leming, Jr. ...............................................................31
The Evolution of the Submarine Telegraph, With
an Extensive Bibliography by Bill Holly.................................73
Broadcast Receiver Manufacture by General Electric and Westinghouse in the First Decade of RCA by Robert Murray.....107

The Evolution of the National HRO and Its Contribution to the Winning of World War II by Barry Williams.....................145

Cumulative Table of Contents and Author Index for Volumes 1 through 17 of the AWA Review............................203

INDEX TO VOLUMES 1 THROUGH 17 BY AUTHOR

<table>
<thead>
<tr>
<th>Name</th>
<th>Volume</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adams, Mike</td>
<td>Vol. 10, page 78</td>
<td></td>
</tr>
<tr>
<td>Anderson, John M.</td>
<td>Vol. 4, page 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 5, page 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 6, page 13</td>
<td></td>
</tr>
<tr>
<td>Anderson, Leland I.</td>
<td>Vol. 1, page 19</td>
<td></td>
</tr>
<tr>
<td>Bacon, Christopher</td>
<td>Vol. 10, page 150</td>
<td></td>
</tr>
<tr>
<td>Balaton, Attila R.</td>
<td>Vol. 4, page 45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 5, page 109</td>
<td></td>
</tr>
<tr>
<td>Bartram, Graeme</td>
<td>Vol. 13, page 39</td>
<td></td>
</tr>
<tr>
<td>Blackshear, Roy S.</td>
<td>Vol. 11, page 150</td>
<td></td>
</tr>
<tr>
<td>Blisard, Karen</td>
<td>Vol. 14, page 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 14, page 82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 16, page 96</td>
<td></td>
</tr>
<tr>
<td>Brelsford, Charles M.</td>
<td>Vol. 1, page 7</td>
<td></td>
</tr>
<tr>
<td>Briggs, Thomas H.</td>
<td>Vol. 5, page 45</td>
<td></td>
</tr>
<tr>
<td>Buzalski, Thomas J.</td>
<td>Vol. 1, page 109</td>
<td></td>
</tr>
<tr>
<td>Byron, William J.</td>
<td>Vol. 7, page 119</td>
<td></td>
</tr>
<tr>
<td>Champeix, Robert</td>
<td>Vol. 6, page 97</td>
<td></td>
</tr>
<tr>
<td>Chaplin, Maurice</td>
<td>Vol. 15, page 147</td>
<td></td>
</tr>
<tr>
<td>Chesson, Frederick W.</td>
<td>Vol. 6, page 49</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 7, page 69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 8, page 123</td>
<td></td>
</tr>
<tr>
<td>Christiansen, Donald</td>
<td>Vol. 3, page 5</td>
<td></td>
</tr>
<tr>
<td>Clark, George H.</td>
<td>Vol. 6, page 1</td>
<td></td>
</tr>
<tr>
<td>Demerseman, Pierre</td>
<td>Vol. 13, page 98</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Volume, Page</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------</td>
<td></td>
</tr>
<tr>
<td>Denk, William E.</td>
<td>Vol. 4, page 99</td>
<td></td>
</tr>
<tr>
<td>Douglas, Alan</td>
<td>Vol. 3, page 61</td>
<td></td>
</tr>
<tr>
<td>Dowd, Pat</td>
<td>Vol. 9, page 205</td>
<td></td>
</tr>
<tr>
<td>Duvall, Edward B.</td>
<td>Vol. 8, page 117</td>
<td></td>
</tr>
<tr>
<td>Eaton, W. A.</td>
<td>Vol. 6, page 1</td>
<td></td>
</tr>
<tr>
<td>Farmer, Paul R.</td>
<td>Vol. 17, page 1</td>
<td></td>
</tr>
<tr>
<td>Fazano, Carlos</td>
<td>Vol. 7, page 91</td>
<td></td>
</tr>
<tr>
<td>Fisher, Charles P.</td>
<td>Vol. 4, page 32</td>
<td></td>
</tr>
<tr>
<td>Foster, Richard C.</td>
<td>Vol. 13, page 98</td>
<td></td>
</tr>
<tr>
<td>Freeman, George A.</td>
<td>Vol. 13, page 124</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 15, page 126</td>
<td></td>
</tr>
<tr>
<td>Friedman, Neil D.</td>
<td>Vol. 9, page 225</td>
<td></td>
</tr>
<tr>
<td>Fuller, Glen C.</td>
<td>Vol. 3, page 120</td>
<td></td>
</tr>
<tr>
<td>Goodnow, A. C.</td>
<td>Vol. 2, page 21</td>
<td></td>
</tr>
<tr>
<td>Grundy, Pamela</td>
<td>Vol. 13, page 115</td>
<td></td>
</tr>
<tr>
<td>Hall, M. D.</td>
<td>Vol. 7, page 151</td>
<td></td>
</tr>
<tr>
<td>Hart, Roger</td>
<td>Vol. 14, page 92</td>
<td></td>
</tr>
<tr>
<td>Havranek, Barbara</td>
<td>Vol. 14, page 178</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 16, page 180</td>
<td></td>
</tr>
<tr>
<td>Heinemann, F. Parker</td>
<td>Vol. 10, page 222</td>
<td></td>
</tr>
<tr>
<td>Herold, Edward W.</td>
<td>Vol. 7, page 15</td>
<td></td>
</tr>
<tr>
<td>Hofer, Stephen F.</td>
<td>Vol. 1, page 43</td>
<td></td>
</tr>
<tr>
<td>Holly, Bill</td>
<td>Vol. 17, page 73</td>
<td></td>
</tr>
<tr>
<td>Horle, L. C. F.</td>
<td>Vol. 6, page 1</td>
<td></td>
</tr>
<tr>
<td>Jones, Al</td>
<td>Vol. 10, page 188</td>
<td></td>
</tr>
<tr>
<td>Kelley, Bruce</td>
<td>Vol. 6, page 1</td>
<td></td>
</tr>
<tr>
<td>King, Kent A.</td>
<td>Vol. 11, page 6</td>
<td></td>
</tr>
<tr>
<td>Kirsten, Charles C.</td>
<td>Vol. 16, page 135</td>
<td></td>
</tr>
<tr>
<td>Kleinman, Russ</td>
<td>Vol. 14, page 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 14, page 82</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 16, page 96</td>
<td></td>
</tr>
<tr>
<td>Kraeuter, David W.</td>
<td>Vol. 5, page 143</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 6, page 155</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 7, page 185</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vol. 8, page 55</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Leggatt, Pat</td>
<td>Vol. 6, page 37</td>
<td></td>
</tr>
<tr>
<td>Leming, John E., Jr.</td>
<td>Vol. 17, page 31</td>
<td></td>
</tr>
<tr>
<td>Link, August</td>
<td>Vol. 16, page 96</td>
<td></td>
</tr>
<tr>
<td>Lozier, Robert</td>
<td>Vol. 7, page 1</td>
<td></td>
</tr>
<tr>
<td>Lyon, Ed</td>
<td>Vol. 9, page 97</td>
<td>Vol. 9, page 181</td>
</tr>
<tr>
<td>MacKinnon, Colin</td>
<td>Vol. 7, page 66</td>
<td></td>
</tr>
<tr>
<td>Matlack, Rexford M.</td>
<td>Vol. 2, page 120</td>
<td></td>
</tr>
<tr>
<td>Mayes, Thorn L.</td>
<td>Vol. 2, page 6</td>
<td></td>
</tr>
<tr>
<td>McCoy, Daniel C.</td>
<td>Vol. 6, page 115</td>
<td></td>
</tr>
<tr>
<td>Meulstee, Louis</td>
<td>Vol. 8, page 1</td>
<td></td>
</tr>
<tr>
<td>Meyer, Stuart</td>
<td>Vol. 2, page 95</td>
<td></td>
</tr>
<tr>
<td>Morris, Robert M.</td>
<td>Vol. 3, page 48</td>
<td></td>
</tr>
<tr>
<td>Nagle, John J.</td>
<td>Vol. 1, page 65</td>
<td></td>
</tr>
<tr>
<td>Nelson, Walter H.</td>
<td>Vol. 8, page 149</td>
<td></td>
</tr>
<tr>
<td>Nelson, Wayne M.</td>
<td>Vol. 1, page 117</td>
<td></td>
</tr>
<tr>
<td>Olson, Hank</td>
<td>Vol. 8, page 75</td>
<td>Vol. 10, page 188</td>
</tr>
<tr>
<td>Orr, Bill</td>
<td>Vol. 8, page 75</td>
<td></td>
</tr>
<tr>
<td>Paquette, Bob</td>
<td>Vol. 4, page 131</td>
<td></td>
</tr>
</tbody>
</table>
Paul, Floyd A.  
Vol. 4, page 84  
Vol. 10, page 245

Peckham, Lauren A.  
Vol. 3, page 79

Schneider, John F.  
Vol. 5, page 123

Sibley, Ludwell A.  
Vol. 3, page 34  
Vol. 4, page 110  
Vol. 7, page 47  
Vol. 8, page 67

Stephenson, Parks  
Vol. 15, page 98

Sterling, George E.  
Vol. 5, page 63

Stewart, Fin  
Vol. 6, page 125

Stinger, Charles J.  
Vol. 16, page 7

Thackeray, Desmond  
Vol. 7, page 29

Trischan, Glenn  
Vol. 14, page 150

Tuska, Clarence D.  
Vol. 1, page 49

Tyne, Gerald F.  
Vol. 8, page 47

Vanicek, Jerry  
Vol. 7, page 107  
Vol. 8, page 107

Vermeulen, Dirk J.  
Vol. 11, page 104

Ware, Lawrence R.  
Vol. 11, page 166

Wiepert, Robert J. & Tina M.  
Vol. 6, page 19

Willer, Murray D.  
Vol. 3, page 98

Williams, Barry  
Vol. 17, page 145

Williams, Ralph O.  
Vol. 1, page 83  
Vol. 2, page 71  
Vol. 3, page 6  
Vol. 10, page 7  
Vol. 12 (entire issue)
NOTES