THE A.W.A. REVIEW

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THE COVER
A photograph of E.H. Scott (right) and an unidentified gentleman enjoying the sound from an extremely rare Scott Telematic receiver. Note the Telematic remote control on the arm of the chair of the unknown gentleman. Although the location is unknown, the photograph was taken on March 25, 1938.

(Photo from the collection of John T. Meredith.)
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Figure 76. The "Sacred Cow." This Douglas C-54 Skymaster was the first presidential aircraft. It is restored and on display at the United States Air Force Museum in Dayton, Ohio. See text on page 84.
Volume 11 of the AWA REVIEW continues the tradition established by the preceding ten issues by presenting four papers which recount events of historical importance in the field of wireless and radio communication. In addition, the over-200 illustrations will be found by collectors to be of considerable aid in identifying areas of interest.

Certainly the story of the E. H. Scott Radio Laboratories is one of the highlights of the golden age of the American radio industry. Written by one of the founders of the E. H. Scott Historical Society, Kent King, who is also the editor of the Society newsletter, this comprehensive and profusely illustrated article traces the emergence of the company in the early days of radio, through its most productive years, to its eventual demise. The contributions of founder E. H. Scott to the technology are recounted, and collectors of these fine and highly sought-after products will find a wealth of material to guide their searches. In addition to illustrations, the author tells of those Scott receivers which are still eluding collectors.

Dirk Vermeulen tells of the beginnings of vacuum tube radio at Western Electric in the early years. Using source material from A.T. and T. company archives, he discusses the development of the equipment from the first efforts to the practical. He tells of the people, including some of the most famous names in radio history. Illustrations include photos of naval and aeronautic radio gear from the World War I era which is still sought after by collectors today, with some success.

A little-known aspect of the development of wireless telephone in the Pacific was the means by which some sort of privacy for the radio conversations was assured. The A-3 Privacy Device, developed by Western Electric, functioned as a voice scrambler for the vital Hawaiian Islands-mainland link between Honolulu and San Francisco. This was in place during the Pearl Harbor attack, and author Roy Blackshear describes the equipment and its history with a well-illustrated article.

The development of the National Company coil-catacomb radios during the mid-1930s under the leadership of James Millen has to be considered, by any standards, as a milestone in communication receiver design. The author, Lawrence Ware, has identified over sixty variants over the thirteen-year production life. This article, illustrated by numerous photos from the original National Company archives, organizes the models into a coherent picture that will be of substantial aid to collectors. Thousands of these radios were manufactured, and while once quite plentiful, they are now becoming scarce.

We hope that this edition of the AWA Review meets with your approval. Suggestions are always welcome.

The Editor
Figure 2. Front view of World's Record Super 9 kit. This set was based on the same design as the set Scott took to New Zealand in 1925.

Figure 2a. Rear view of World's Record Super 9 kit. Note the trimmer capacitors on the IFs, and the fiber posts to raise the tube sockets up to the IF transformers.
Ernest Humphrey Scott came to the United States following World War I. A native of New Zealand, Scott was a talented and motivated man, and he saw the U.S. as a place where he could easily pursue his interests in emerging technology. Ironically, Scott entered into the radio business somewhat by accident. One of the best accounts of the company’s beginning was written by Scott himself in 1939:

"The business really started in 1924, the year I established four Verified World’s Records for the reception of stations 6,000 to 9,000 miles distant, using a superheterodyne receiver incorporating a number of my own ideas. This reception record created world-wide attention, and the publicity given it was what practically forced me into the radio business.

"When these reception records were published in various radio magazines and newspapers throughout the country, I received hundreds of requests for information on the receiver that had accomplished this remarkable reception record, for in 1924 a receiver that would bring in programs from stations over 2,000 miles away was considered a good radio, but one that was powerful enough to bring in stations 6,000 to 9,000 miles distant was sensational.

“I wrote a small booklet giving information on how to construct my receiver, together with a list of the parts used, and sold over 700 copies of it at $5.00 each. However, many of those who purchased the book and built the receiver, when they found they could not secure the kind of reception I secure with my receiver, called on me for advice and help to make their receiver perform like mine."

World Record Superheterodynes (8 and 9 Tube Models)

As Mr. Scott stated, he did not offer complete sets or even kits of parts initially. To build his set "by the book," there were a couple of components that Scott required the set builder to order from him. Otherwise, the parts required were widely available, including Thordarson audio transformers, Carter rheostats, Benjamin tube sockets, Sangamo condensers and a Jewell "double reading" panel meter. The first set described in the $5 plan book also used Remler IF transformers.
Figure 1. The earliest known national advertisement for Scott radios. From Radio Age magazine, November, 1925.

Scott incorporated several unusual techniques into his set, and he attributed its fine performance to these features. First, the tube sockets are all mounted on posts of fiber rod, providing an almost direct connection from the sockets to the Remler IF transformers. Scott believed (correctly), that by reducing this distance he would realize fewer signal losses and reduce interference. The Scott circuit used two tuned and two untuned amplification stages, while most superheterodynes of the period used three untuned and only one tuned circuit. Scott felt (again correctly) that the second tuned circuit provided better selectivity. Even though the amplification was not as great, the set was still stronger than comparable sets of the day. Finally, Scott had spent considerable time testing radio components, and felt that his list of parts represented the finest materials available at the time.

Building a World Record Super was not cheap, however. Scott ultimately offered a complete kit of parts, including an engraved panel. Without a cabinet or tubes, the parts alone totaled over $100. Adding tubes and a cabinet, the builder could easily find himself spending about $125 for the Scott receiver. For this reason, and the fact that a set of this complexity was not easy to build, very few original World Record Super 9 sets exist today. Although Mr. Scott ran ads in a variety of magazines as early as November, 1925, he needed a means to get his designs into more set builder hands. Beginning in the spring of 1926, articles describing his receiver and plans to build it began to appear in several popular radio magazines.
The earliest magazine article discussing Scott radios appears in the April, 1926 edition of *On the Air*. Titled “The Quest for the Ideal Receiver,” author Felix Anderson was obviously quite taken with the Scott receiver, as the article is a glowing revue of the set and its capabilities. The writer also emphasized the tonal quality of the radio, a feature that Scott would be most intent upon by the mid-1930s. Although not a construction article, a schematic is shown. It closely matches the original circuit described in the Scott $5 plans, but the final audio (AF) stages use 201A tubes, rather than a pair of UX-220 tubes as shown in the original plans. (The article itself mentions a final AF of two UX-220 tubes, in contrast to the diagram.)

During these early days, Scott’s address in advertisements and articles is listed as 35 S. Dearborn St., Chicago.

By the late summer of 1926 Scott was inundated with requests for plans, additional help and troubleshooting. One of the largest problems was the matching of the intermediate frequency (IF) transformers. Scott had quickly noted that the people who ordered “matched” sets of transformers were less likely to experience problems than those builders who had simply purchased plans, and bought parts elsewhere. Scott commented on this in his 1939 history:

“The secret of my original receiver’s performance was the perfectly matched set of four I.F. transformers used in it, and also the fact that for the first time two tuned air core I.F. stages were used in the I.F. amplifier instead of what had been the standard practice up to that time - one tuned air core and three untuned iron core transformers. If these transformers were not perfectly matched, the performance of the receiver was no better than the ordinary set. As it was impossible for the set builder to secure matched sets of these transformers in stores that sold radio parts, I was practically forced to go into the business of supplying them, for at that time I had one of the few pieces of laboratory equipment in the country that was capable of matching these I.F. transformers.”

By September, 1926, Scott ran his first ad for Selectone transformers in the *Citizen’s Radio Callbook Magazine*. This ad is also the first appearance of “Scott Transformer Company,” a name that Scott would use for the next five years. Scott had also moved into larger quarters at 9 S. Clinton St., Chicago.

Mr. Scott’s notoriety allowed him to write a description of his set in *The Chicago Evening Post Radio Magazine*. In the issue for October 14, 1926, a ten-tube schematic is shown and described. This set is basically
the same receiver as the earlier nine-tube sets, but has a parallel final output tube, which gives the ten-tube count. It is doubtful that this set is notably better than the earlier versions, except perhaps in battery consumption.

By this time, Mr. Scott had begun to establish a solid reputation for his World Record receiver. How Mr. Scott and the editors of *Radio Age Magazine* came together is unknown today, but Scott obtained considerable coverage in several articles that would generate volumes of business for the Scott Transformer Company in 1927.

**Radio Age, November 1926**

Entitled “Radio Age Adapts World’s Record Super To Storage Battery Use;” the article described the first of several eight-tube variations of Scott’s circuit. The tube lineup of this set (and all subsequent eight-tube sets) includes an oscillator, the first detector, and three IF stages, a second detector and two AF stages. The *Radio Age* circuit is the first to show 201A tubes throughout, and suggests either a 112 or a 171 in the final audio stage, claiming this removes any need for a ninth tube. Most of the recommended parts follow previous lists, except that Yaxley rheostats are now specified.

The circuit varies only slightly from the original nine-tube set. In the first set, volume control was obtained by varying the filament voltage of the audio tubes. *Radio Age* added a rheostat across the plate circuit of the second IF tube, effectively grounding the signal. Additionally, the
oscillator and final audio tubes were separated by individual Amperite regulating resistance units, providing better stability, particularly in the oscillator circuit.

*Citizen’s Radio Callbook, December 1926*

Although it is unclear how much of the *Radio Age* design can be directly attributed to Mr. Scott, he obviously felt that an eight-tube design was worth promoting. For Christmas, 1926, Mr. Scott ran a two-page ad in *Citizen’s Radio Callbook*. This is also the first ad showing Mr. Scott’s new address at 7620 Eastlake Terrace. The ad ran in conjunction with a construction article, entitled “How to Build the Latest World’s Record Super.” The circuit is virtually identical to the *Radio Age* diagram, although the parts list specified Dubilier condensers, Frost tube sockets and Rauland “Lyric” audio transformers.

One of the most interesting items in the article is the extensive list of “extras” recommended for use with the World’s Record Super. Among them are: a trickle charger manufactured by the Storad Mfg. Co. of Cleveland, OH (type 201), a Troubadour speaker and the Qualitone loop, both manufactured by Duro Metal Products of Chicago, and cabinets by Signal Electric in Menominee, MI and the Charlotte Furniture Co.
SCOTT’S NEW WORLD’S RECORD
SUPER 9
DISTANCE
The New World’s Record Super 9 has power “to burn.” It brings in distant stations and puts them on the speaker with almost unbelievable volume. It is designed by E. H. Scott who holds four verified World’s Records for the reception of stations 6,000 miles or more distant.

SELECTIVITY
Today’s conditions demand a receiver that is capable of bringing in without interference stations 10KC apart. The World’s Record Super 9 uses five perfectly matched Selectone Long Wave Transformers, two of which are filters. These filters are sharply peaked to a 10KC cut off, thus giving maximum selectivity without cutting useful side band frequencies.

We Have Complete Sets of Parts for This Marvelous Receiver and Can Ship Your Order Promptly

Price for complete set of parts including drilled and engraved panel, $91.15

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The World Is Our Market—We Ship Everywhere

Radio Age, January 1927

“Unprecedented interest” was how Radio Age described the reader response to the November, 1926 article. To satisfy this demand, the article “Full Data on Building World’s Record Super 8” was published in the January, 1927 issue. The set is more completely described, and exact component layouts and panel drilling diagrams are provided. To further promote this set, Scott purchased a four-page advertisement for the World’s Record 8 and the associated component manufacturers, including the Scott Transformer Co.

Around this time several other companies advertised plans and parts for building “World’s Record” sets. The relationships between these companies and Scott are not known, but attest to the popularity of his receivers. Some examples include the M-S Syndicate in Cleveland, Ohio and Hudson-Ross, Inc., of Chicago.

Citizen’s Radio Callbook, March 1927

In the March issue of Citizen’s Radio Callbook, there is an article simply titled “World’s Record Super Nine.” This variation of the nine-tube circuit is significantly different from the earlier nine-tube sets, and
contains the most unique tube lineup of all the Scott battery receivers. Described as a "revised model" from the December, 1926 article, the major revision is the addition of a fourth IF stage. This is accomplished by using WX-12 tubes in the IF, supposedly to lower the grid to filament capacity, reducing the tendency to oscillate. The set uses filament controls for volume, and also returns to the lower ratio Thordarson audio transformers in the audio stages. Including the recommended type 171A final audio, the set uses 201A tubes for the oscillator, first and second detectors, and the first AF stage. Four WX-12s in the IF complete the nine tube lineup. The Qualitone loop is again recommended for use with this set.

Radio Age, March 1927

As if the "new" nine-tube set in Citizen's Radio Callbook wasn't enough, Radio Age associate editor F. A. Hill published an article in the March issue, entitled "Building Ideal Model of the World's Record Super 8." This article attempts to take the basic Scott circuit and presents the first "sub-panel" construction plan for the set. Previous sets in both Radio Age and Citizen's Radio Callbook had departed from one of Scott's major themes, short lead lengths to reduce capacitive effects. By using a sub-panel approach, placing the IF transformers underneath the main construction platform, leads between the Selectone transformers and the IF tubes were again brought to minimum lengths. The article also mentioned that the set worked quite well using a type 112 tube as the second detector, especially for strong stations.
Another interesting fact with this set is the recommended use of Silver-Marshall audio transformers. Scott's notorious rivalry with McMurdo-Silver did not begin until the 1930s. Since McMurdo Silver was a contributing author to Radio Age, it is unclear whether Mr. Scott approved this design change. It may be that the publishers of Radio Age used Silver's components to appease McMurdo Silver. This set also returned to Sangamo condensers in the parts list. It is very likely that component choices were significantly influenced by advertising revenue.

This same article also described a "171 Power Compact." The Power Compact is a "B" eliminator using an 85 ma QRS rectifier tube. The Compact also provides a 5V ac filament supply for the type 171A final audio tube. The user must still provide an "A" eliminator for the remaining tubes in the set. The article recommended using a Balkite battery charger, filtered by an "Abox" filter block, manufactured by the Abox Company of Chicago.

Radio Age, May-June 1927

This issue of Radio Age contains two articles of interest to Scott collectors. Mr. Hill wrote another article on "Using 9 Tubes on World's Record Super." The circuit is the same as the previous Radio Age article, with the addition of a fourth IF stage to make nine tubes. This is also the first sub-panel version of a nine-tube set. It is interesting to note that the parts list again returns to Thordarson audio transformers.
Perhaps more interesting than the construction article is the article on page three of the May-June issue. The article, “Trouble Shooting on Supers” is one of the earliest magazine articles written by Mr. Scott himself. The article is really a “cookbook” of solutions to common problems with any battery superheterodyne. Many of the problem descriptions are based on a Scott nine-tube diagram shown at the beginning of the article. The article is written for novices, but contains data seldom seen at that time, including bandpass curves for IF transformers. This article is quite helpful for the contemporary radio restorer.

Throughout the summer of 1927, Scott continued to advertise Selectone transformers, plans and parts kits to build the various eight- and nine-tube supers. In November, 1927, a final article, “World’s Record Super Eight is Economy Model for 1928,” appeared in Citizen’s Radio Callbook. This set is very similar to the previous eight-tube sets, but does recommend Silver-Marshall audio transformers. For almost two years, Mr. Scott had been quite successful with a single basic set. In the fall of 1927, the handwriting was on the wall, as better circuit designs started appearing in various publications. Mr. Scott was ready to meet this challenge with his second major development, the World’s Record Super 10.

**World’s Record Super 10**

*Citizen’s Radio Callbook, September 1927*

With a flashy two-page ad on pages 78 and 79, and a detailed construction article beginning on page 92, Mr. Scott introduced the World’s Record Super 10. The 10 shows major changes and improvements from the previous eight-and nine-tube sets. The greatest improvement in the World’s Record Super 10 is in the “front end.” For the first time, we see a Scott set with two stages of tuned RF. This is accomplished with the newly announced Remler “3-in-line” tuner. The tuned RF stages also eliminate the need for a loop antenna to create regeneration as in the previous design. Following the two RF stages, the signal is mixed with the oscillator output and fed into three IF stages. Following the second detector, there are two AF stages, the last being a type 210 power amp. With the additional RF stages and a 210 output, the World’s Record Super 10 developed quality sound that was unmatched by other battery receivers of the period.

It is obvious from the plans that keeping the Scott Transformer Co. in business would be easier with the Super 10. The set required eight separate Selectone transformers, all being the new “sub-panel” mounting that Scott was producing. In addition to the Selectone transformers, this set returned to Benjamin sockets, Thordarson audios and Carter rheostats. The one new manufacturer on the parts list is Tobe condensers.

The list of sub-panel transformers required to build a World’s Record Super 10 includes all of the following: B-500 IF Transformer, B-510
Tuned Filter, B-520 RF Transformer, B-530 Antenna Coupler and a B-540 Oscillator Unit. In addition to the sub-panel transformers, Scott also offered the following baseboard mount units: R-400 or R-500 air-core and the R-410 or R-510 iron core. The oscillator coupler was also available in baseboard mounting.

Mr. Scott advertised the Super 10 heavily, running one-, two- and sometimes four-page ads in many radio magazines. He also managed to get larger number of magazines to carry construction plans for the set. World’s Record Super 10 articles can be found in all of these publications:

Citizens’ Radio Call Book, September 1927.
Radio Age, October 1927.
WCFL Radio Magazine, October 1927.
Radio News, November 1927.
Citizen’s Radio Call Book, January 1928.
Radio World (series of articles), March 24, March 31 and April 7, 1928.

Although drawn in different styles, the basic circuit remained the same. Each magazine had some gimmick or modification to the basic set, however. The article in Radio Listener’s Guide and Callbook, September, 1927, shows a 171A output tube, rather than the type 210. In the December issue, Radio Listener’s Guide and Callbook provided plans for a “Light-Socket Operated World’s Record Super 10.” This set was quite unusual,
using Sovereign ac tubes manufactured by Sovereign Electric & Manufacturing Company of Chicago. Plans for a complete “B” eliminator, which also provided filament voltage for the Sovereign tubes (and a type 210 output tube) were given. The Sovereign tubes used a cold cathode, so the diagram is somewhat different from the typical Super 10 schematic. The January, 1928 Citizen’s Radio Callbook article described how to add a phonograph pickup to the audio section of the set. To boost the AF stages slightly, this article used a 112 tube as the first audio. The 1928 articles mention a Thordarson “A/B” power supply, using two 281 rectifier tubes. This supply also provided filament potential for the 210 output tube. The Radio World articles are of particular interest, since E. H. Scott authored them.

Radio parts catalogs and “wholesale” suppliers began to carry Scott sets in their catalogs as well. The Super 8 and Super 10 both appear in a 1928 Barawik Co. catalog. The Barawik catalog also advertises a “Selectone Two Stage RF Super Amplifier,” which will “increase the range of any super.” The list of parts is virtually the same as the RF section of the World’s Record Super Ten, built on a bakelite panel approximately seven by eleven inches.

Although there are no sales figures available for 1925 or 1926, the large number of transformers required by the Super 10 obviously contributed to a good year. Scott sales in 1927 were just over $32,000, which was certainly not bad for a “basement” business. The success of the World’s Record Super 10 might allow Mr. Scott to sit back and reap the benefits and profits of another well designed radio receiver, but Mr. Scott was never one to sit still for very long. 1928 would be a very good year for Mr. Scott.
Shield Grid 9

In the March, 1928 issue of Citizen’s Radio Callbook, Scott announced a “great, new receiver.” Looking only at the panel, the set would appear to be a World Record Super 10, but with a new name stenciled in the upper right corner of the panel: “Scott Shield Grid World’s Record Super 9.” Although no examples of this prototype version of the Shield Grid 9 are known to exist, enough of the set is shown in the ad to make some guesses as to its design and tube lineup. Three facts noted in the ad include “Only 1 stage of audio necessary,” “Actual 10 K.C. Selectivity,” and “3 Stages of shield grid giving 140 gain per stage.” While the last claim is probably somewhat extravagant, it is quite likely that this receiver could obtain 10 kc selectivity.

While no schematic exists, the layout of the tubes and the claims gives us the following lineup: two stages of RF, using 201A tubes, similar to the World’s Record Super 10. This is mixed with the oscillator output (another 201A) at the first detector. The first detector could be either a 201A or possibly a 240. The 240 was used in the later versions of the Shield Grid 9, and had been available almost a year (RCA introduction in February, 1927). The signal is then passed through the three IF stages, using the UX-222 screen grid tubes introduced by RCA just six months earlier, in October, 1927. The second detector is another 201A, followed by the single audio stage, which is most likely a type 112A or 171. The set is obviously a “battery” set, but that is hardly surprising, since ac
tubes would not appear until later that year. This set appears in one other ad in *Radio News*, May, 1928. After that, we see nothing of the Shield Grid 9 until August.

In the August, 1928 issue of *Radio News*, the full page Scott ad is almost identical to the May ad, but the receiver shown is now the set that most collectors recognize as the Shield Grid 9. The front panel is changed, and the large copper IF section is visible. The other RF and AF transformers are enclosed in larger copper cans as well. Interestingly, the three major "claims" in the ad are now somewhat different. The claim of a single audio stage has been changed to "Can be built by anyone in 4 hours." The 10 kc. selectivity claim has been amended to include "Actual 10 kc. selectivity with perfect tone quality." The 140 gain per stage claim has been changed to "3 stage shield grid amplifier gives tremendous gain." Apparently, the rather extravagant claim of 140 gain was at least somewhat questionable. The ad also mentioned the availability of a new power supply amplifier, using a type 250 output tube. Scott’s intention was obviously to enter the AC-set market as quickly as possible.

The August *Radio News* ad is notable for another reason: For the first time, we see Scott has moved his operation to the famed Ravenswood Avenue address on Chicago’s north side. Scott would remain in the building at Ravenswood and Sunnyside until he retired from the company following World War II. Early ads give the address on Ravenswood as 4446-4448. Later, Scott advertised from 4450 Ravenswood, the address most Scott collectors recognize today.

The first full description of the Shield Grid 9, and a wiring diagram, appear in the September, 1928, issue of the *Citizen’s Radio Callbook*. The final design of the Shield Grid 9 shows that Scott has used only a
single RF stage, with a small amount of regenerative signal returned from the first detector. The set actually has only eight tubes on the chassis: RF (201A), oscillator (201A), first detector (240), three IF stages (222), the second detector (201A) and an audio stage (112A). The ninth tube is the type 250 final audio on the power supply unit. Scott did not count the rectifier tubes at this time (two type 281 half-wave rectifiers). For the kit builder, the IF unit came as a single, factory sealed installation. The wiring of the set was therefore greatly simplified, and IF alignment problems were eliminated. It is quite likely that a competent kit builder could meet Scott’s claim of four hours to build.

Scott continued to promote the Shield Grid 9 with construction articles in several radio magazines. *Radio Listener’s Guide and Callbook* had articles on the Shield Grid 9 in both their September and November issues. Scott also ran another article in the November, 1928 issue of *Citizen’s Radio Callbook*. This article introduced a slightly different version, called the Shield Grid 9B. Apparently, many of Scott’s customers were still without a source of ac power in their homes. The 9B is a fully battery operated version of the Shield Grid 9, with nine tubes on the tuner chassis. Scott’s 9B is almost identical to the original 9, but the audio transformer (Scott designation #640) is replaced with a “double audio transformer,” designation #641. (The article mistakenly refers to this as the #645 unit, but the parts list and known sets all contain a #641 transformer.) Early samples of the #641 transformer are in a wider than normal, black transformer casing. Later sets have the #641 transformer in a matching copper can. A final audio stage using a 171A output tube.
is wedged onto the chassis. With this arrangement, full loudspeaker volume is available without the use of the power supply/amplifier unit.

In each of these articles, we see Scott's earliest attempt to capture a new market: The Shield Grid 9 receiver is able to operate not only in the broadcast band (200-550 meters), but also in several short-wave (SW) bands. Three of the square copper cans are actually plug in coils (the can at the right rear of the chassis is the unmoving audio transformer). Interestingly, each article seems to mention a different availability for the SW bands. The *Citizen's Radio Callbook* November article states that coils are available for the 20-50 meter and 35-90 meter ranges (about 6 to 15 MHz and 3 to 8 MHz respectively). The *Radio Listener's Guide and Callbook* article mentions coils for 80, 40 and 20 meters. A W.C. Braun radio parts catalog shows coils for 70-210 m and 30-75 m. (About 1.5 to 4 MHz and 4 to 10 MHz.) Very few SW coils are known to exist today. One existing set, marked as noted in the W.C. Braun catalog, test very closely to the ranges specified in the catalog.

Scott claimed that the Shield Grid 9 was the first truly "All-wave" radio offered to the radio public. The Shield Grid 9 was certainly a very popular set for Scott, and must have sold fairly well, as quite a few examples exist in collections today. Sales figures for 1928 also bear out the popularity of the Shield Grid 9. Sales increased over 500%, totaling $175,000 in 1928. However, the ac power capability of the set was not a truly "built-in" feature. By the 1928 Christmas season, most large manufacturers were offering fully integrated ac sets. So, in less than a year, Scott found his Shield Grid 9 receiver trailing slightly behind the leaders in ac power. A fully dedicated ac set was needed from the Scott Transformer Company.
Figure 14. The AC 9/Symphony ad, Radio Listener’s Guide - April, 1929. Scott’s first venture into ac operated receivers.
Figure 15. AC 9 receiver. A unique set, unknown in contemporary collections. (Enhanced view from advertisement.)

The First AC Only Receivers

A most unusual and informative ad appeared in at least two publications in the spring of 1929. The April issue of Radio Listener's Guide and Callbook, and the May issue of Radio News both contain a flashy two-page ad for two new Scott "AC" receivers. Dubbed the World's Record AC 9 and the Symphony, these are perhaps the rarest of the pre-chrome Scott sets. Indeed, the author is unaware of any AC 9 receivers in any collection at this writing. There is no other documentation available on the AC 9, and very little on the Symphony.

Worlds Record AC 9

The picture of the AC 9 in the ad shows a rather unique receiver. The tube lineup shows no tubes with grid caps. This leaves one to assume that the set is probably mostly type 27 tubes, except for the output stage, which is likely a type 71A. Two tubes are located adjacent to the tuner in the center of the chassis. Most likely, these are an RF stage and the oscillator. The seven remaining tubes are situated in a line on a slightly raised platform just in front of the "completely shielded intermediate amplifier." This row would include the first detector, three IF stages, a second detector and two audio stages. No mention is made of a separate power supply, but as there is no power transformer on this chassis, the set would probably have had an external supply unit. A close approximation of this circuit would probably be the RCA Radiola 60.
Pictured in the same advertisement is the “4 tube” ac Symphony. The Symphony has the distinction of being the only receiver ever offered by Scott that was not a superheterodyne design. Although not a superhet, the Symphony once again shows Mr. Scott pushing the technology of the day to its limits. On April 20, 1929, RCA announced the 224 tube, an ac version of the popular screen grid 222. Scott, however, had beaten RCA to the game: The Symphony ac incorporates a type-222 ac tube, manufactured by the Shieldplate Tube Co., Inc., of Chicago. This tube is electrically almost identical to the 224, but had been introduced in late 1928. Scott used the shield grid tube as the RF amplifier in a highly unusual regenerative circuit. The regeneration is returned from the type-27 detector, via inductive coupling. The remaining tubes are both audio stages, a 27 in the first stage driving a 71A output. The audio transformer used is designated #640-2, and is the same as the double audio transformer on the Shield Grid 9B. The power supply contains a type-80 rectifier, but Scott was not counting rectifier tubes in his lineups quite yet.

The Symphony definitely does not perform as well as previous Scott sets. By all accounts Mr. Scott was not totally pleased with the Symphony, and his lack of enthusiasm is reflected in the very small amount of advertising seen for this set. Although the Symphony does not appear again in magazine advertising, the 1929 Scott full line catalog does show the ac version. Given the numbers that survive in collections today, it is doubtful that Scott sold many of these receivers. The performance of the DC Symphony is unknown, as no known examples exist in contemporary collections. One document states that the DC Symphony required three 01A tubes and a type-71 output, but little more is known.

Worlds Record AC 10

In July, 1929, Hugo Gernsback launched his newest radio magazine, Radio Craft. In the premier edition, we find a column ad announcing the new Scott Shield Grid ac 10. A two-page ad also appeared in the July issue of Radio magazine, and by September, a complete article and two-page advertisements appeared in the Citizen’s Radio Callbook. As described in the Callbook article, the AC 10 uses type 224 tubes for the first three IF stages. All other tubes on the tuner chassis are type 27 (oscillator, first and second detectors, fourth IF stage and first audio stage. Final audio amplification is on the power supply, using two of the relatively new type-45 output tubes in push-pull. The two type-80 rectifiers are not counted in Scott’s lineup. The amplifier is designed to feed an eight-inch electro-dynamic speaker. At this time, Scott obtained speakers from the
Rola company, but had decals applied to the speaker showing the Scott name.

The AC 10 circuit has a number of changes from the previous designs. Scott has eliminated the separate RF stage, mixing the antenna transformer directly with the oscillator output. Volume control is obtained by varying the cathode bias on the common connection between the three type 24 IF tubes. The set contains a fourth IF stage, and the IF line is peaked at a somewhat non-standard 480 kc. The compatibility of the 222AC and the type-24 tube is also evidenced in the AC 10. One apparently early schematic of the tuner chassis clearly shows 222 ac tubes for the first three IF stages.

The AC 10 survived from its 1929 introduction through the fall of 1930, slightly over a year. Although it coincides with the stock market crash and the onset of the Great Depression, the AC 10 sold well, and underwent some modifications during this time. The first versions of the set sported a large, bronzed face plate covering the entire area around the tuning window and controls. Later versions have a much smaller dial scale, and use a small bronze escutcheon shaped like an inverted cathedral. In early 1930, the circuit was upgraded to use a type-24 tube as the first detector. Additionally, the volume control was extended from biasing the three IF stages to include the cathode of the first detector. The result was a slightly more responsive volume control action. Finally, the transformer coupling between the second detector and the first AF stage was replaced by a resistance coupling, probably to reduce parts costs. The power supply also received an upgrade. The rectifier was reduced to a single 80 tube, and a type-12-20 line regulator tube was added to improve set voltage stability.
Although the AC 10 enjoyed a long life (as Scott sets go), its success was undoubtedly helped by the variety of accessories that Scott offered for the AC 10. One of these was an “outboard” short-wave converter. Packaged in a copper case not quite six inches square, the short-wave converter used three coils to cover wavelengths from 3.9 Mc to just over 20 Mc (36-76m, 23-40m and 14-25m). User operation wasn’t trivial, requiring the user to remove the oscillator tube altogether, and move the first detector from the set to the converter. The converter then plugged in to the first detector socket, and the set was tuned only from the converter.
Sales literature also states that a dc version of the short-wave converter was produced, to be used with the Shield Grid 9 sets. Why this was done instead of the existing plug-in coils is unknown today, although the performance of the converter might have been better (and covered a wider range) than the Shield Grid 9 coils previously offered.

Another notable accessory for the AC 10 was a remote control. This was not a mechanical remote, but rather an electrical one, have a set of tuned coils to allow user selection of up to eight preset stations. Housed in a walnut box about the size of a cigar box, the first Scott remote control was both functional and unobtrusive. This remote was heavily advertised, appearing in several magazines in the spring of 1930. *Citizen's Radio Callbook* also ran an article “Scott Designs Remote Control for His Screen Grid Super” in the March, 1930 issue.

In addition to the remote control and the short-wave converter, a January, 1930 order form listed the following accessories: A walnut cabinet with dynamic speaker at $60, a console electro-magnetic speaker at $15, a Scott radio bench (similar to a piano bench) at $22, and the short-wave converter and remote control at $32.50 and $50 respectively. Given the relatively small volume of Scott sets, these new accessories undoubtedly helped Scott greatly in getting through the first difficult year of the Depression.

**Automobile Radio**

Another area that Scott delved into rather briefly during this time was automobile radios. Scott was quite qualified to work in this realm, as during World War I he was a troubleshooter of motor vehicles, and patented and built a service device called the Telecator. He had, therefore, a solid understanding of the difficulties in placing electronics in motor vehicles. The only reference to auto radios is found in the September, 1930 issue of the *Citizen's Radio Callbook*. In a single page article entitled “Superheterodyne Circuit Adapted for Automobile Radio Receiver.” Scott described his automobile radio.
The set is battery operated, obtaining “A” voltage from the ignition battery, and with the “B” cells in the back. The antenna could be either a copper mesh in the ceiling or a wire hidden in the running board. A small schematic is given, showing the following tubes: two type-27 tubes in the oscillator and second detector, three type-24 tubes for the first detector and two IF stages, a 71A as the first audio stage and a 45 as the final audio. Even using these seven tubes, Scott claimed the set only drew 25 mA from the “B” cells. The article leads one to believe that several versions might have been built. The last paragraph states that “later models of the receiver show change in that a 227 tube is used for the first audio, and a 171A for the output instead of the combination shown in the diagram.” The article also mentions that a special water- and dust-proof Utah magnetic speaker is used with the set.
Chrome Beginnings

Up to this point in time, Mr. Scott had sold all of his sets through custom “kit-builder” offerings. Scott promised “protected” territories, and strong incentives to sell, assemble and install his radios in a specific area. This also had another welcome (but planned) side effect. By selling kits, Scott was not running afoul of the harshly protected RCA superheterodyne patents. Scott sales continued to improve, rising to $385,000 in 1929.

The Depression was taking its toll on America, however. Scott’s sales were down noticeably, and would total only $235,000 for 1930. This gave Mr. Scott his first year of decreased sales since his start in radio. Mr. Scott realized that he needed a set that could be sold and installed directly by the consumer. During the summer of 1930, Scott and his staff designed what would become the first of the famed chrome chassis receivers. In building this set, they would also receive the attentions of David Sarnoff’s giant legal machine.

All-Wave Superheterodyne

Mr. Scott’s first entry into the assembled radio business was also the first chrome chassis set built by the Scott Transformer Company. Announced in the October, 1930 issue of “The Scott News,” a prototype is shown, with a number of variations from the more widely recognized version of this set. This chassis is arranged differently, allowing room for six holes on the right side of the chassis. These holes were the holders
for three pairs of short-wave coils accompanying the radio. Outside of the description in *The Scott News*, and what appears to be the same picture in the November, 1930 issue of *Citizen's Radio Callbook*, no other mention (or examples) of this set are known. The frequency coverage of this set is also questionable. In a January, 1931 article in *Citizen's Radio Callbook*, coil ranges are listed as follows: 15-21m, 21-31m, 31-51m, 51-105m, 105-200m and the AM band from 200-545m. This selection of frequency coverage apparently changed almost immediately. All subsequent magazine articles and the coils found with sets today cover: 15-21m, 21-27m, 27-38m, 38-84m, 84-184m and the broadcast coils from 200-550m. The small gap in coverage in the latter coil list would allow for the 470 kc intermediate frequency of this set.

Using the short-wave bands on the 1931 "All-Wave" is somewhat tedious. Two coils (oscillator and RF) must be replaced, and two grid caps must be changed for some of the bands. Also, the set does not operate correctly on the short-wave bands if the coil covers over the two replaceable coils are present. To keep the user from placing the wrong coil in the wrong socket, some sets had a four-pin coil form for the oscillator (with a center pin to close a contact switch on some wavebands). The RF coil is wound on a five-pin form. Other sets used the same five-pin coil forms for both coils, but one of the oscillator socket holes on the chassis was riveted shut to prevent insertion of the wrong coil. Some of the very last sets saw a minor improvement in the short wave operation: Scott added a contact switch under the RF plug-in coil. This allowed a single grid cap lead to the RF tube, making the correct setup and operation less tedious (and less error prone) for the user.

In addition to numerous one- and two-page ads in popular radio magazines (*Radio News, Radio Craft, Citizen's Radio Callbook, Radio Callbook Magazine and Technical Review, Short Wave Craft* and others), several reviews and articles were written about the Scott "All-Wave." *Radio News* ran a two-part article entitled "Stepping Out for World-Wide Reception" in the June, and July (1931) issues. The June article also mentions a unique accessory, the microphone/phono control box. This allowed the user to make pressed recordings using the All-Wave amplifier, in addition to the phonograph connections. *Radio Craft* has an article on "The New Scott All-Wave Superheterodyne" in the July, 1931 issue. This was followed by a DX report written by Marcellus Gernsback, appearing in the September, 1931 issue of *Radio Craft*. Gernsback was very complimentary of the tone and tuning ability of his test receiver. Not to be out-done, *Radio News* ran a DX article "Experimental Reception On the World's Tallest Structure" in the November, 1931 issue. (At that time, the tallest structure was the Empire State Building.) Finally, *Radio
Figure 23. Allwave tuner and coil set. The first chrome chassis from Scott. The tube shields and coil covers are brushed aluminum, however.

_Callbook Magazine_ and _Technical Review_ had a brief analysis in their December issue, including a variety of sensitivity and selectivity curves. Heavy advertising of the 1931 Allwave continued through June, 1932.

The eighteen-month run of the Allwave is notable for any Scott receiver. However, it underwent remarkably few changes during its life. None of the published schematics vary significantly, and the tube lineup remained the same. This included type-24 tubes in the RF, first detector and all three IF stages and type-27 tubes for the oscillator, second detector and a push-pull first audio stage. The three remaining tubes in the 12-tube count are the 80 rectifier and the two push-pull type-45 outputs on the power supply. The set slightly predates the development of an automatic volume control (AVC) circuit. Volume control was obtained by varying the bias voltage on the screens of all the 24 tubes.

Having had some success with “add-ons” and accessories, Scott offered several options to buyers of the Allwave. One is the aforementioned microphone control box, while another was the auditorium amplifier and speaker. The “typical” set came with a large (12”) Rola speaker, with the Scott decal applied. The auditorium option included a larger power supply/amplifier using two type-81 half-wave rectifiers, providing sufficient power to run a pair of push-pull type-50 tubes. The speaker was also upgraded to a heavier pedestal unit. The speaker manufacturer of the pedestal unit is unknown, as no “auditorium” versions of the Allwave have yet been found. Scott also offered a 470 kc test oscillator, and the IF coils on the Allwave are user adjustable. This probably caused frequent service requests to the factory, and all subsequent Scott sets have the IF adjustments well removed from the user.

Although this was Scott’s first chrome chassis receiver, this set differs from all the later chrome sets. On the All-Wave Superheterodyne, the
coil covers and tube shields are brushed aluminum. The chassis and rectangular covers over the tuning capacitors are the only chromed parts of the tuner chassis. The power supply is chromed, but the core of the power transformer is exposed. All later sets have a chrome band between the outer plates to completely hide the transformer core. As previously mentioned, the IF adjustments are available to the user; later sets would not be as easy to adjust.

Even in the depths of the Great Depression, the new Allwave Superheterodyne proved very popular. Scott sales rebounded to $458,000 in 1931, not quite doubling the 1930 sales figures. However, sales of almost ½ million dollars, and a completely assembled superheterodyne receiver were noticed by RCA. Mr. Scott now had the undivided attention of RCA and their large staff of patent litigation attorneys.

The Patent Situation

During the 1920s, RCA gathered together a large number of key radio patents from GE, Westinghouse, AT&T and their own efforts, and forced many manufacturers to obtain licenses. The primary focus was on large (in excess of a million dollars) corporations, and in fact Crosley, Atwater-Kent, Grebe and many others signed with RCA in the latter half of the 1920s. By offering kit or “custom-builder” sets, and due to relatively small sales volume, Scott remained unnoticed until the introduction of the Allwave Superheterodyne. With this set, RCA took notice, and was probably even more angered that Scott was selling a superheterodyne, since those patents were generally not included in the 1920s licenses. In 1932, RCA took Scott to court, but the case was settled amicably, and Scott now had access to about 140 key patents and designs. Scott also signed with Hazeltine for their patent rights, and so had a free hand in radio design for the remainder of the decade.

Another change at the E. H. Scott Radio Laboratories was the addition of a full-time Chief Engineer. Up to this time most set designs were a collaborative effort between Mr. Scott, Clifford Coon and Arthur Finney, both long time Scott employees. Although the Allwave Superheterodyne was an unparalleled success for the company, the dual dial tuning, plug-in coils and antenna matching all needed significant improvement. In 1932 Scott hired Ernest R. Pfaff away from Silver-Marshall. Pfaff had extensive design experience, having worked for Western Electric and Temple Radio prior to working at Silver-Marshall. Mr. Pfaff’s influence was felt almost immediately with the announcement of the Allwave 12 Deluxe in May, 1932.
Allwave Deluxe

The Deluxe model announced in 1932 immediately solved two of the most visible problems with the Allwave. First, the plug-in coils were eliminated by using the new turret tuner designed by Mr. Pfaff. The tuner system resulted in patents #1,986,525 and #2,035,668. A single-dial control was also developed, and Mr. Scott’s mechanical engineer, George Roethel, Jr., designed a positive-motion tuning drive with unmeasurable “lost motion” between components. The dial mechanism was also patented, a few months after the turret tuner patents. The first widely publicized picture of the Allwave 12 Deluxe appears in the July, 1932 issue of every major radio magazine.

The circuitry of the Deluxe model is quite similar to the 1931 Allwave. A type 51 replaced the type-24 RF tube. The type-27 tubes are all replaced by the newer type-56 triode. The power supply/amplifier is almost
unchanged, although the early Deluxe sets had a dual speaker, rather than the larger single speaker previously offered. The set does not have any automatic volume control. The most significant difference from the 1931 Allwave is in the audio stage. The second audio stage is no longer push-pull, but is separated into two capacitively coupled single stages, rather than a transformer-coupled push-pull circuit. This gives the Deluxe three audio stages, rather than two as in the 1931 Allwave.

Scott managed to obtain some impressive magazine coverage for his latest receiver. *Radio News* ran a three-article series in the August, September and October, 1932 issues. Author S. Gordon Taylor spends a bit of time waxing on both the DX capabilities and on the set’s “fine tone quality and overabundant volume”. More interesting is the article in the November, 1932 issue of *Radio Craft*. Written by Scott himself, this article is also
Figure 25. Schematic of Allwave Deluxe AVC, Wunderlich detector circuit. Scott's first set with an AVC circuit. A dramatic improvement from the previous version of the same set.

the only known publication with a schematic of the tuner chassis of the early Allwave Deluxe. With performance curves and a fairly detailed description of the set, Scott provided some of the most complete information on this chassis in a few short pages.

The Deluxe was a hit, but Mr. Scott and Mr. Pfaff were not sitting idly by. With access to the RCA patents, and the development of a new, rather novel tube named after its inventor (Wunderlich), the Deluxe was modified heavily in late 1932. Ernest Pfaff also developed a visual tuning indication (which would later be patented). These changes left the Deluxe almost unchanged externally, but the circuit differences are so vast that it could be argued that the next receiver was a totally new design. Most of these changes came with the addition of an automatic volume control circuit (AVC), driven from the unique Wunderlich detector.

The Wunderlich tube was designed specifically as a superheterodyne second detector. The tube has a cathode, two meshed grids equally spaced between cathode and plate, and a heater. A center-tapped IF output is attached to the two grids. The IF center tap connects to the grid-leak, and through a load resistance also becomes the IF AVC output. The AF signal appears on the plate. This full-wave detection results in a clean separation, with virtually no RF or IF signal entering the audio stage. Coupled with the gain a Wunderlich affords, the resulting quality is indeed high. Until the type-55 dual-diode triode became available, the Wunderlich was an excellent alternative to a typical half-wave detector using a type-27 or 56. In retrospect, the Wunderlich filled the same
niche that the 222AC had several years earlier. Until a better, more universal choice was available, Scott used “fringe” technology to build the finest radios possible.

In addition to the Wunderlich second detector, the entire RF and IF sections of the tuner were redesigned. The RF amplifier used the new type-58 pentode. The type-58 is also used for the three IF stages. The first detector (mixer) is a 57. The audio stages continued to use the 56 triodes, in a slightly modified circuit that is still capacitively coupled. Volume control is via the more traditional signal level feed into the first audio stage and a tone control is added in the plate circuit of the first AF stage. The tuning meter is connected to the plate circuit of the Wunderlich detector, resulting in a direct measure of the actual signal strength. Finally, Scott moved away from the dual speakers offered earlier, and returned to a single twelve-inch “auditorium” speaker.

Radio News again evaluated the AVC version of the Allwave Deluxe in a pair of articles appearing in March and June, 1933. Again, author S. Gordon Taylor emphasizes tone quality and sensitivity. The action of the AVC also apparently impressed the test listeners, and once again Scott received very favorable reviews for his newest design. This success, and the fact that Scott had not returned to his native New Zealand since the famed 1924 trip led Mr. Scott to decide it was time to take another working vacation. In February, 1933 Scott left from San Francisco aboard the RMS Maunganui. He took with him the latest AVC Deluxe set, in the new Napier “console.” Mr. Scott documented reception of station WBBM Chicago every single night on the trip. In addition, the set provided ample volume to use the Deluxe as a receiver and amplifier for the evening.
dance music. These reception reports and testimonials were published in the Scott News throughout the spring and summer of 1933, and were also heavily featured in full-page ads in major radio magazines that year.

Mr. Scott's success during this time is notable. Although 1932 sales ($408,000) were not quite as high as 1931, we see the company absorbing the costs of modifications and new developments in the one and only receiver the company has to offer. Also, there are almost no accessories for the Allwave Deluxe. Gone is the "remote control" tuning of the AC 10, and outboard shortwave converters. It is not even clear that a larger amplifier is available for the Deluxe model. Only one accessory is even mentioned: a "4000-meter adapter," which plugs in to a four-prong female connector on the back of the chassis. Even though Scott had only this one set to offer for calendar year 1933, sales improved to $482,000.
Figure 28. Allwave 15 tuner and power supply. The Fifteen underwent tremendous circuit change while remaining essentially the same cosmetically.

Allwave 15

The Allwave 15 is one of the most volatile sets ever developed by the E. H. Scott Radio Laboratories. Produced from February, 1934 through March or April of 1935, there are more documented variations of the Allwave 15 than any other Scott set. Several Scott brochures describe Type I, Type II and Type III Allwave 15 sets, but four different tube lineups and five schematics have been found through the years. There is no other way to describe the Allwave 15 than as a transition set, moving from the Allwave Deluxe to the Allwave High-Fidelity (Imperial) in 1935.

All variations of the Allwave 15 used a greatly improved power supply/ampifier, with the newly announced 2A3 power triode. The resulting increase in output, and the greater tone of the set can be attributed to the use of 2A3 outputs. The rectifier tube is a 5Z3, providing ample current for the 2A3 outputs as well as the twelve tubes on the tuner chassis. The Allwave 15 supply is otherwise similar in appearance to the Allwave Deluxe supply, built on a chassis frame that is slightly deeper, but otherwise the same size as the Deluxe.

The evolution of the Allwave 15 tuner chassis is best examined by looking at the existing schematic diagrams. Only two diagrams are found in Rider’s, simply listed as the “early” and “late” versions of the set. These two diagrams represent the last variants of the Allwave 15. The earliest diagram is dated April 10, 1934, and is probably the first schematic drawn for the circuit. This set is remarkably similar to the Allwave Deluxe, with the addition of three tubes: a tuning meter amplifier, a BFO, and a second audio stage that is push-pull and transformer coupled. This gives a lineup of a 58 RF, four 58s in the mixer and the 465KHz IF stages, a Wunderlich second detector, and 56 tubes in the oscillator, tuning meter amplifier, BFO, and the first and second (two tubes, push-pull) audio stages.
The set began the revision cycle very quickly, and the next schematic is dated May 7, 1934. There are two significant changes in the May drawing. The April diagram has a five-position switch for the sensitivity, varying the antenna coupling and the IF bias simultaneously. The diagram also has a tone adjustment in the plate circuit of the first audio stage. The May diagram eliminates the five-position switch, in favor of a continuously-variable bias adjustment for the IFs. In addition, the tone control is removed, and replaced by a “static control switch,” which cuts in a filter in the plate circuit of the first audio stage. This version of the Allwave 15 is easily distinguished by the static control switch, which extends from the tuner chassis on a loosely twisted pair of wires.

The third schematic is much later, dated November 19, 1934. It is quite probable that several other schematics were drawn in the time between May 7 and November 19, since the November diagram states “improved AVC,” and “revised.” The tube lineup demonstrates some of the changes: 58 RF, 2A7 mixer, three 58 IFs, a 55 detector/amplifier, and the ubiquitous 56 tubes in the remaining functions. The static control switch is gone, replaced by a typical tone control. The sensitivity control is now a two-pole, three-position switch, varying the RF and IF bias on one pole, and the cathode bias of the second detector on the other. The second detector is configured in a half-wave arrangement, with both 55 diodes tied to one end of the IF output, and the AVC voltage and signal developed on the cathode and plate respectively. This diagram was modified again on January 12, 1935, although the only difference appears to be the bias resistor on the second AF stage. The value was lowered from 2000 ohms to 1500 ohms.

The last diagram is the diagram in Rider’s, labeled Allwave 15 “late.” No other date is attached to this diagram, but it must be one of the last revisions of this chassis. Once again, the sensitivity control is altered, now a simple single three-position switch that varies only the bias on the first and second IF tubes. Also, the second detector circuit is changed, using a center-tapped secondary on the IF output. This creates a full-wave second detector, and the AVC voltage is developed from the center tap through a resistive network. Finally, the cathode bias on the second AF stage is again a 2000 ohm resistor, but 1000 ohm resistors have been placed in the grid leads from the coupling transformer.

Unfortunately, the changes for the Allwave 15 don’t stop here. The six-month gap from May to November 1934 probably saw more variations of this chassis. This assumption is bolstered by the fact that these five schematics only represent two different tube lineups. Scott literature lists another tube lineup, referred to as “Type II,” which uses a 57 tube in the mixer stage. Another documented lineup includes a 2A7 mixer with the Wunderlich detector tube. The evolution of the Allwave 15 can best
be summarized by the mixer and second detector tubes: first the 58 mixer with the Wunderlich, followed by the 57 mixer and finally a 2A7. The last sets use the 2A7 with the 55 second detector. The schematics encompass the first and last lineups, so the missing six-month interval in the diagrams dates the two other variations quite closely.

The Allwave 15 was also a test bed for high-power audio-amplifier circuits. Mr. Scott and the then Chief Engineer Murray Clay created a special amplifier for the Allwave 15. Shown in Rider’s, the special amplifier diagram is dated August, 1934. The unit has two 5Z3 rectifiers which power four 2A3 tubes. A type 26 tube tied as a diode provides bias for the 2A3s. This amplifier is tied to a very unique speaker that contains a double voice coil. Sales literature offered this special version of the 15, with the Warwick Grande cabinet and a record changer, for the rather hefty bill of $1500. Quite a sum during the depths of the Depression.

Although coming rather late in the life of the Allwave 15, Radio News did run one feature article in the March, 1935 issue. Again written by S. Gordon Taylor, the article “Informal Tests on a 13-550 Meter Superhet” stated that the set has remarkable sensitivity and an “unusually favorable signal-to-noise ratio.”

Scott advertised the Allwave 15 almost as heavily as the Deluxe model. Full-page ads appeared in all major magazines beginning in April, 1934. By summer, the ads were reduced to single column, and in some cases, ½ column ads. The Depression was taking its toll on Mr. Scott’s advertising budget, even though sales were quite good. Scott did save a few dollars.
Figure 30. Allwave 15 "Special" amplifier schematic. A unique circuit upgrade, the beginning of high-fidelity sound.

for full-page ads in the December issues. These efforts resulted in 1934 sales of $568,000.

The changes seen in the Allwave 15 are impressive, and provided a solid basis for the next major Scott receiver. However, before moving on to one of the most impressive Scott receivers, it is worth taking a moment to note the battery-operated versions of the twelve- and fifteen-tube sets produced in the first half of the 1930s.

The Allwave Battery Sets

Other than the Quaranta series later in the 1930s, no other group of Scott sets commands as much speculation as the DC models of the Allwave series. In a March, 1933 sales brochure and price list is the "Scott Allwave Deluxe DC Model." The $107.50 price includes the set, speaker and tubes. The user had to provide the batteries, listed as one "A" air cell, four 45-volt "B" cells and two 7½-volt "C" cells. This set, referred to as the Allwave Two-Volt, is built on the same chassis as the standard Allwave Deluxe. The schematic in Rider's shows an eleven-tube set, with a rather unique lineup: 34 RF, type 30 oscillator, a 1A6 mixer, three 34 tubes for the 465 KHz IF stages, type 30 tubes in the second detector and first two AF stages, and a pair of 30s as a push-pull final audio stage. One
example in a collection demonstrates Mr. Scott’s custom built philosophy: The set has a twelfth tube, another type 30, as a BFO. The position and layout of the tubes is almost identical to the Allwave 15, and examples that exist today may well date from that period. This is also evidenced by the schematic drawing in Rider’s, dated December, 1934.

The next clue in the set mystery is found in a sales brochure from September, 1933. Here, the “Scott Allwave Deluxe Battery Receiver” (at the same $107.50 price) requires a six-volt “A” battery and three 45-volt “B” cells. Although there is no other documentation on a six-volt set in 1933, one set exists that uses a six-volt filament lineup, and looks like a standard Allwave Deluxe receiver. Although the set was modified in the audio stages, it is not hard to determine the correct tubes: 78 RF, 37 oscillator, 77 mixer, three type 78 tubes in the IF, a six-volt Wunderlich second detector, a 76 first audio and a pair of 38 tubes for the push-pull final AF stage. The extra final audio tube is the only addition to what is otherwise a chassis drilled exactly like the standard twelve-tube Deluxe receiver. The existing set is also identical to a ten-tube chassis that appears in ads in the October, 1932 issues of Short Wave Craft and Radio News. It may well be that Mr. Scott was building dc sets almost from the beginning of the Allwave Deluxe development.

Several years ago, a schematic was discovered for a “Scott Allwave Twelve 6-Volt Battery Set.” Sporting two drawing dates (March and August, 1934), the set could be built on an unmodified Allwave 15 chassis. In fact, an example was found in early 1997, and the component layout is identical to the Allwave 15 chassis. The tube complement consists of type-78 tubes in the RF, mixer and three IF stages, a 76 oscillator, a six-volt Wunderlich second detector, a 30 as a BFO and another 30 as the first AF stage, a 31 second AF, and a pair of 49 tubes in push-pull for the final AF. The set matches the schematic quite closely, according to the owner.
If we engage in some pure speculation, we see three of four possible set arrangements. There could be two dc sets built around the Allwave Deluxe receiver (two-volt and six-volt versions), and two more built on the Allwave 15 chassis. Schematics, an owner’s manual, and examples exist for both the “later” versions, built on the Allwave 15 chassis. These are the previously mentioned Allwave two-volt with the added BFO and the six-volt set found recently. The March, 1933 sales brochure provides a clue that a two-volt set existed during the reign of the Allwave Deluxe, but only a six-volt example exists (identical to the “mystery” ads that appeared in October, 1932). It seems likely that a nine- or ten-tube two-volt set could exist, and would “round out” the dc models that Mr. Scott offered during the first half of the 1930s.

Allwave Imperial High-Fidelity

Second only to the Philharmonic, the Allwave High-Fidelity receiver is one of the most well-known classic Scott pre-war sets. In sales volume, the 23-tube Allwave may have even surpassed the Philharmonic, as slightly more Allwave 23 sets appear to exist in collections today than the Philharmonic. Beyond the obvious success of this receiver, no other set sparks as great a debate among collectors than its immediate offspring, the Quaranta. Between the Allwave 23, the Quaranta receivers and the Philharmonic, the period from 1935 to 1941 has to be the pinnacle of development at the E. H. Scott Radio Laboratories.

Under the guidance of Chief Engineer Murray Clay, development of the Allwave High-Fidelity began in the winter of 1934-35. Enough new developments had been tested that the Allwave 15 chassis and design simply could not accommodate the changes required. Scott announced the High-Fidelity in the March, 1935 issue of the Scott News as a 22-tube receiver, although there is no evidence that any 22-tube sets were produced. Later that year (in the September, 1935 issue) Allwave Radio had an extensive article on the 22-tube Allwave High-Fidelity. The photo with the article does show a 23-tube set, however.

As presented in the Allwave Radio article, the High-Fidelity set had a 6D6 RF stage, 76 oscillator, 6A7 mixer, 6B7 RF AVC, three 39/44 IF stages, a 6D6 fourth IF, a 6A6 second detector/first AF, two 76 tubes in a push-pull second AF stage, a 6A6 as the noise suppressor/BFO, and a 6B7 and 6A7 as a tuning-meter amp and signal equalizer. The remaining tubes are the two rectifiers (one 83V and one 5Z3), and four 2A3 tubes in a push-pull parallel final audio stage giving 35 watts class-A output. The tuner chassis also uses two type-NE-42 regulators, making up the 22-tube count. The type-6A6 dual triode was ultimately abandoned in the final design.
The first sets actually delivered to the public were 23-tube sets with five knobs (not counting the bandswitch) and a BFO button. The final tube lineup included the same rectifiers (83V and 5Z3) and four 2A3 tubes on the amplifier. The tuner still used the two NE-42 regulator bulbs, a 6D6 RF stage, 6A7 mixer, 6B7 RF AVC, three 39/44 IF stages, a 6D6 fourth IF, type-76 tubes for the oscillator, second detector, noise suppressor, tuning meter amp and BFO, and three 6C6 tubes in the first and second AF stages. The 6C6 tubes are all tied as triodes, and the second stage is push-pull. Using the 6C6 tubes tied as triodes provides almost 50% more output to drive the 2A3 final stage than using 76 triodes.

The Allwave High-Fidelity had impressive features for a 1935 set: fully regulated local oscillator, separate AVC for IF and RF stages, noise suppressor, and the audio provided from the four 2A3 tubes is 35 watts class A, and 50 watts class AB. Sensitivity is advertised as 0.6 uV, and the operator has full variable selectivity from 2 kc to 16 kc. An optional tweeter set ($16 extra) would provide audio response beyond the transmitting capabilities of the day, up to 16 kc. The set also offered a low impedance phono input. The set almost fit on the Allwave Deluxe/15 chassis. The width and height are the same, but the Allwave High-Fidelity is 3/4" deeper (front-to-back) than the Deluxe/15. The basic set ranged in price from $180 to several hundred dollars for very ornate cabinets.

Scott's success led him overseas, and the firm Keates & Co., Ltd. of London was a distributor of the Scott Allwave High-Fidelity in the United Kingdom. The UK sets appear to be identical to the US versions, although the attenuators and trimmers are different values to allow for the 9 kc separation of European transmitters. Scott even managed a feature article...
in the December 20, 1935 issue of Wireless World. After noting that the top model in the Warwick Grande cabinet would cost over 600 pounds, the last few sentences sum up the Allwave quite well: “The privileges of possessing such a receiver are naturally reserved for the few, but the humbler amateur will not, on that account, withhold his appreciation of the technical merit of the design.”

In addition to the overseas commentary on the Allwave High-Fidelity, Mr. Scott managed to get extensive magazine coverage on the set here in the US. In June, 1935, both Radio Craft and Short Wave Craft ran feature articles. Allwave Radio ran the article describing the 22-tube set in September (possibly later than the other articles due to publishing delays). Radio News ran a two-part description in the May and June, 1936 issues. Scott also returned to extensive full-page advertising, often near the front of major magazines.

In March, 1936, the set underwent some minor changes, including new IF trimmers ("air condensers" in the service literature), changed phono input to high impedance, and added a separate noise limiter control to the front panel. By moving the BFO from a push-button to a symmetrical knob (with the noise limiter knob), the “late” version of the Allwave High-Fidelity has seven knobs on the panel. Many “late” receivers had a drum-wheel “vernier” indicator just below the tuning dial as well. The Scott "Serviceman’s Bulletin" indicated that warranty repair work after this time should include the new IF trimmers in older versions of the chassis. This same bulletin states that sets with serial numbers greater than 500 have some small change in the parts used. This is the only known indication that Scott did, in fact, use a sequential serial number system.
In late 1936 Scott offered an outboard "volume expander" to be used exclusively with the Allwave High-Fidelity. During the 1930s considerable development went into volume range expander circuits. The need for a "volume expander" is due to the wide variations in level that a normal musical piece will deliver. A full orchestra commonly has a range of 70 decibels or more between the loudest and softest passages. This represents a ratio of 10 million to one, if we express the output in watts. Typical transmitters of the 1930s could deliver 45 to 50 decibels of volume range, far short of the 70 plus that would be required for full reproduction. So a volume "expander" within the radio seemed to be the answer.

A volume expander circuit could almost be called a "reverse AVC" system. With an AVC circuit, we want to lower the amplification of very strong local signals, and favor weak, distant signals. With the volume expander, we want to amplify loud passages even more, while leaving quiet passages unaffected.

Referring to the basic expander circuit diagram, the input signal is applied to both the 6L7 and to a 6C5 amplifier simultaneously. The output of the 6C5 is rectified in the 6H6, providing a positive voltage with respect to the reference on the voltage divider. This bias signal is applied to the other input grid of the 6L7, where it produces an initial large negative bias. Under normal sound, the amplification factor of the
6L7 is low, but with louder passages the gain is increased in proportion to the signal strength. Thus, quiet passages are unaffected, while louder passages are “expanded.” The amount of expansion can be set by the control. It is also possible to set a threshold signal level; this is done by biasing the rectifier tube to the desired level. There is a required time constant for the control voltage on the 6L7 as well. Typically, the RCA data recommends a time factor of between 250 and 500 ms. If the time constant is too short, speech sounds unnatural. Too long a time negates the desired effect of the circuit.

Scott used two different volume-expander circuits: one for the “outboard” expander sold with the Allwave 23 High-Fidelity, and another incorporated onto the chassis in the Philharmonic receiver. The unusual “Baby Quaranta” or Allwave 27 has the outboard expander circuit built onto the receiver chassis as well. Both of Scott’s expander circuits resemble the basic RCA diagram, except that both are built in a push-pull configuration. The Allwave 23 outboard expander uses 6A7s in place of the yet undeveloped 6L7. The expander driver is a 6C6, and is rectified by a type-76 triode tied as a diode. The diagram for the outboard expander can be found in Rider’s.

The Allwave High-Fidelity was undoubtedly Scott’s greatest success to date. Sales in 1935 soared to $690,000, a truly impressive number with such an expensive receiver in the Depression. The technology was impressive as well, and the basic design of the Allwave High-Fidelity, the speaker systems and the volume expander all provided a solid foundation for Mr. Clay to build what would become one of the largest radio receivers built by any manufacturer of any time: the famed and mysterious Quaranta.
Quaranta

Although all Scott sets were "Custom-Built," none were more "custom" than the Quaranta sets. Virtually no verifiable information exists as to the number of sets built or their features. Being extremely wealthy (the lowest known price for a Quaranta is $2500), most of the purchasers of these sets remain a mystery even today. The whereabouts of one 48-tube set is known, and various component chassis for other units have been found over the years. More recently, Chief Engineer Murray Clay located some of the schematic diagrams for the Quaranta. By using this information and a few photographs, some educated guesses about the composition of the sets can be made. Mr. Clay recalls that less than ten, and possibly only six or seven of the largest sets were ever built. Finally, the smaller 27-tube Allwave set, alternately referred to as the "Baby Quaranta" or Allwave 27, seems to be found with some frequency, but has the distinction of being the only Scott set with absolutely no written information of any kind located to date. So, in order of increasing tube count, here are the few facts known about the Quaranta line.

The smallest of the series is the Allwave 27, or Baby Quaranta. The most noticeable difference between the Allwave High-Fidelity and the Quaranta set is the upgraded tuner chassis. A tuning eye replaces the patented back-lit tuning meter. A second eye tube indicates the volume expander action (in place of the meter in the RCA diagram previously presented). The seven knobs are slightly repositioned, giving the appearance of a larger set. The two eye tubes create a 19-tube tuner chassis. The amplifier for the Allwave 27 is really a "stretched" version of the High-Fidelity supply, to make room for two additional tubes. These tubes,
and changes on the tuner chassis, combine the late Allwave High-Fidelity and volume expander into a single receiver.

The lineup on the tuner chassis of the Allwave 27 is identical to the High-Fidelity up through the second detector. In addition to the two eye tubes, the remaining tubes are type-76 tubes as noise suppressor, expander rectifier and first AF stage, and two 6A7 tubes and a 6C6 in the expander circuit. The two additional tubes on the power supply are the 6C6 push-pull second audio stage. The Allwave 27 also appears to come “standard” with a fifteen-inch speaker, rather than the twelve-inch speaker used in the High-Fidelity. The Allwave 27 fits comfortably in the large Ravinia Grande cabinet, which can also house a record player/cutter unit. Two of the known Allwave 27 sets are configured like this.

The Allwave 27 has the distinction of being the only Scott set with no supporting documentation. One reference that might be related to the Allwave 27 is found in the Scott Serviceman’s Notes, Volume 1, Number 5, dated April, 1936. In this document, a “special amplifier, using an additional pair of 6C6 tubes,” is available for the Allwave High-Fidelity. The $135 price also includes an eighteen-inch Jensen speaker. The set is supposedly for larger listening areas, such as a theater or funeral home. The basic description fits the Allwave 27 quite well, and the number of sets remaining suggest that if this is the same set, Scott sold a fair number of these “upgraded” receivers. In relative terms, quite a few of these sets exist in collections today. An exact number is not known, but at least seven of the Allwave 27 sets are confirmed.

Although none of the 40-tube sets are known today, this is the set that actually inspired the name “Quaranta”, which is Spanish for forty. The 40-tube set again starts with the 19-tube tuner with the two tuning eyes. All the 40- and 48-tube sets had a large bass/mid-range amplifier that really looks like two Allwave High Fidelity power supplies joined
together on the long side. On a single large frame are two power transformers, four filter chokes, and three interstage transformers, along with eight 2A3 tubes and four rectifiers (two 83-V and two 5Z3s). This arrangement makes one of the heaviest single chassis in any Scott receiver. The 40-tube set also had an eight-tube "mid-amplifier," which used six 6C6 and two 6D6 tubes as amplifiers for each of the separate audio signals. This gives us 39 tubes, and the 40th tube is most likely a 6F5, found on the "Record-o-Matic" booster amplifier. Two fairly good pictures of the 40-tube sets exist, one in the May, 1936 issue of the Scott News, and another in a very brief article in the August, 1936 issue of Short Wave Craft. The exact date for the Quaranta is hard to determine however, since the set also appears in a picture of the Scott New York sales studio in the January, 1936 issue of the Scott News. The five-speaker complement for the 40-tube set includes an eighteen-inch Jensen bass speaker, two twelve-inch mid-range speakers and a pair of horn tweeters. Scott stated that the combined weight of this set was 615 lbs.

The Scott News for April, 1936 shows a picture and description of a 48-tube Quaranta receiver. This set incorporates the same three main chassis as the 40-tube set (the nineteen-tube tuner, the large, heavy twelve-tube main amplifier, and the eight-tube mid-amplifier). In addition, a seven-tube recording amplifier chassis is included. The record amplifier chassis is similar to the Allwave 27 amplifier, but has only one 6C6, rather than the two found on the Allwave 27. To get to 48 tubes (if you're counting, we're at 47 right now), the one-tube pre-amplifier is
replaced by a two-tube, push-pull pre-amplifier, using a pair of 6N7 tubes. The 48-tube set appears to use the same five speakers found in the 40-tube set. The 48-tube set is also mentioned (without the Scott name) in “The Latest Radio Equipment” section of the September, 1936 issue of *Radio Craft*.

The Quaranta series offered the wealthy buyer a number of quality features not found on other sets of the day. Scott's extremely high sensitivity, noise limiter and volume expander circuits, and the use of the relatively new tuning eye tube all make for an appealing and functional receiver. The three separate audio amplifier “channels,” 30-125 cycles on the bass channel, 100-6000 on midrange and 3000-16000 on the “treble” channel provide the listener with highly advanced audio, rated at 100 watts continuous Class A. No company would build an audio amplifier of such capability and power again until well after World War II.

To conclude the discussion of the Quaranta sets, we must end with a few mysteries. As mentioned previously, two schematic diagrams have been found for the Quaranta. The tuner diagram has a slightly different tube lineup, showing a 6H6 as the second detector. However, none of the known Quaranta tuners (the 48 tube set or the Allwave 27 sets) have a 6H6 as the second detector. The other diagram is for a ten-tube mid-amplifier. In addition to the six 6C6 and two 6D6 tubes, this diagram shows a pair of 6L7s as a part of the expander circuit. Since no examples of the ten-tube mid-amplifier have been found, it is not clear how this would fit into a 40- or 48-tube set. If the two-tube recording amplifier is removed and the eight-tube mid-amplifier is replaced with the ten-tube unit, it does create a 48-tube set without the recording capability. Finally, there are rumors that Scott built at least one set with more than 50 tubes, but no information exists about its chassis configuration.

Each of these sets represents a distinct period of experimentation at the E. H. Scott Radio Laboratories. Chief Engineer Clay used the very expensive, highly-customized sets to design new circuits and improve various features of the Allwave High-Fidelity. Although the number of Quaranta special installations is unknown, the popularity of the basic-23 tube set and the special offerings took Scott sales to a new high in 1936, reaching just above $3/4 million dollars, to $786,000. These developments and the introduction of the new octal-based tubes in 1935 and 1936 ultimately resulted in the creation of the most well-known Scott receiver, the Philharmonic.

**Philharmonic**

In the April, 1937 issue of the *Scott News*, the E. H. Scott Radio Laboratories announced their newest receiver, the Scott Philharmonic. With the exception of the highly custom Quaranta sets, the Philharmonic...
Figure 39. Various mid-1930s consoles. Most sets were offered with a low-end cabinet which would provide a discount to the better quality cabinets.
was the largest and most complex receiver Scott had ever offered. At the same time that Scott sent out the *Scott News* to his customers, he placed "teaser" ads in several national publications. Full-picture ads appeared in the June issues of most major magazines, and by August, 1937, *Radio News* had started a series of three articles describing and testing the Scott Philharmonic. In addition to being considered the finest of the Scott "standard" sets, the Philharmonic enjoyed one of the longest production intervals of any Scott receiver. When launched in the spring of 1937 the Philharmonic would undergo modifications, but remained available until the start of World War II. This was also the first Scott set to incorporate the "Stradivarius" logo, and the May, 1937 teaser ad in *Radio News* is the earliest national appearance of the now famous symbol.

The Philharmonic circuitry is the basis for all Scott sets built between 1937 and 1941, so a thorough examination of the set is required. All other models produced during this time use reduced size variants of the basic Philharmonic design, such as fewer RF or IF stages, and reduced audio amplification. Almost all the previous Scott circuit designs are included in the Philharmonic, including the noise limiter, expander, and variable bandwidth IF and AVC systems for both RF and IF stages. The Philharmonic also used all octal-based tubes (with the exception of the eye tubes and rectifiers). In the sometimes heated discussion regarding the merits of glass and metal octal tubes, Scott always maintained that the glass tubes were superior to the metal designs. Until the FM circuits were introduced, Scott always recommended glass octal tubes in his receivers.
The Philharmonic is a large and impressive 30-tube receiver, covering 150 kc to 80 Mc in six bands. With a chassis of 23” W X 17” D X 11” H, and weighing in at approximately 60 lb., the tuner itself is massive. Add in the amplifier (34 lbs) and a three-speaker sound system, and the Philharmonic receiver without a cabinet totals over 125 pounds. The Philharmonic also does away with the original patented drum dial that is found on the Allwave series. The first Philharmonic sets are often called “pointer” sets by collectors today, since they have a metal pointer to indicate the stations on a large glass “airplane” style dial face. Later, the pointer was eliminated, and a projected beam of light indicated the station selection.

The tube complement of the Philharmonic begins with two 6U7 tubes for the two tuned RF stages, a 6L7 mixer and a separate 6B8 RF AVC. The control voltage for the RF AVC is obtained directly from the output of the 6L7 mixer. The oscillator is a 6J5, with stabilized plate voltage provided by a 0D3 (VR150) regulator. There are four IF stages, three 6K7s and a 6B8, which also functions as the second detector. A 6B8 IF AVC is fed from the second IF output, and a 6H6 sensitivity diode/noise limiter complete the RF sections of the receiver. The antenna circuit employed a newly patented noise reduction system, which still maintained 0.5uV sensitivity. The antenna coupling is covered under patent #2,172,923 and the RF rejector is patent #2,226,468. The variable bandwidth IF allowed full 16 kc audio, a feature not seen on AM receivers again until decades later.

Following two 6J5 single AF stages, there is a push-pull volume expander using a pair of 6L7s, and a 6J5 and 6H6 as the expander amplifier.
Figure 42. Antenna-coupler patent diagrams. The improved antenna designs of Murray Clay enhanced the performance of the Philharmonic.

Figure 42a. Antenna-coupler patent diagrams.
and rectifier respectively. In addition, a 6B8 and a 6J7 make up a phonograph scratch suppressor circuit. Clay filed for a US patent on the scratch suppressor, but was denied. However, he did obtain a British patent (#519,486) for this circuit. The expander output is fed into a pair of 6J5 tubes used as a push-pull third AF stage, and finally, the signal goes to the power supply/amplifier chassis, where four 6L6 tubes in parallel push-pull deliver 40 watts of class-A audio. The bass adjustment provided +/- 20dB control, and included a 60-cycle notch filter to minimize hum when using increased bass. Like the High-Fidelity, the Philharmonic could be purchased with optional high-frequency speakers, giving the set an audio range from 30 to 16,000 cycles. Advertised at less than 1% THD, the amplifier would not take notice today, but in 1937 the audio capabilities were unmatched.

A set of this size required considerable power (almost 300 watts), and the DC supplies initially used a pair of 83-V rectifiers. A pair of 5Z3 tubes quickly replaced these. The FM Philharmonic sets used a pair
of 5U4 rectifiers. A pair of “eye” tubes rounds out the thirty-tube complement, one for the tuning indication, and the second to indicate expander action.

In a comparison of the early schematic (dated May 15, 1937) and the “revised” diagram dated April 4, 1939, a number of changes are obvious. The treble control is changed to a fully variable control, and the bass compensation now uses an R/C network, rather than a choke. Biasing changes for the tuning indicators and the IF AVC circuit improve the action of these systems somewhat. Finally, the UHF band antenna circuit was improved. These changes were probably introduced gradually, but sets without the “pointer” (also called the “Beam-o-Lite” sets) all appear to include these modifications. Additionally, Scott separated the selectivity and fidelity controls, which gave later Philharmonic sets a nine-knob front-panel layout. Finally, the tuning indication with the Beam-o-Lite tuner is not as precise as the pointer dial, and a logging scale was added in a small window near the top of the dial face. The ultimate evolution of the Philharmonic prior to the FM versions is a Beam-o-Lite set, with the logging scale and the nine front-panel controls.

Adding the FM circuits to the Philharmonic required some modifications. While the basic AM section did not change significantly, the Philharmonic was altered to remove the expander circuit, to make room for the FM components. With the expander removal, the first AF stage was changed to a 6K7. The second AF stage is combined with an inverter stage in a 6F8. Another 6H6 is added as a separate Dickert noise limiter. The second tuning eye remained, becoming the FM tuning indicator. The
basic FM circuit will be discussed at some length later, but even after the removal of the expander, the FM Philharmonic was still a 33-tube receiver.

**Sixteen & Eighteen**

With the price of a Philharmonic approaching $300 without a cabinet, Scott realized that he needed to have a set available at a somewhat lower cost to the consumer. For the first time, the E. H. Scott Radio Laboratories began to offer more than a single model of set at the same time. In June, 1937, the Sixteen was introduced. It is a “scaled down” version of the basic Philharmonic design, and incorporates most of the same tubes. The Sixteen had a direct offspring, the Eighteen, which adds the scratch-suppressor circuit using the 6J7 and 6B8 tubes. Both the Sixteen and Eighteen are quite unique in the late 30’s Scott line, as they are the only sets to not have a glass dial face. The Sixteen had a metal dial, reminiscent of the General Electric sets of the period. Not nearly as handsome as the Philharmonic, they are often shunned by contemporary collectors, but are a fine performer nonetheless.

The Sixteen has only one stage of RF, using the 6U7, feeding the 6L7 mixer. The 6J5 oscillator is not stabilized with a regulator, and the IF is trimmed to just three stages (two 6K7 and a 6B8 which doubles as the second detector and the IF AVC). A 6K7 first AF and a 6J5 inverter move the signal into a pair of push-pull 6J5s for the second AF. Final audio is a pair of 6V6 outputs. A tuning eye and two 5V4 rectifiers
round out the Sixteen tube complement. The Eighteen has the two additional scratch-suppressor tubes, and can be easily identified by two (rather than a single) push-pull switches under the dial.

The Eighteen was offered in a unique phonograph arrangement called the Autotrope. The Scott Autotrope could stack and play both sides of up to thirty albums, providing hours of continuous music. Unfortunately, there are no known units in contemporary collections. The Autotrope was featured in the December, 1937 Scott News. A review of the Sixteen appears in Radio News in a brief article in the March, 1938 issue. An operating company (British Ozaphane) working under license from the E. H. Scott Radio Laboratories also built the Sixteen in the United Kingdom. Several of the British sets have survived, using 220V, 50-cycle power.
The appearance differs slightly from the domestic version, and a long-wave band was available for these sets as well.

Both the Philharmonic and the Sixteen could be obtained with a “Robot Control” feature. Unlike Scott’s earlier remote unit, the Scott Robot Control was a mechanical remote control, with a motor drive on both the volume control and the tuning drive. Station presets were movable “stops” placed on a semi-circular disk mounted on the back of the chassis. The station stops were fine enough to provide very good AM presets, and many shortwave stations could also be programmed. The remote control was a small bakelite control with a long ribbon cable, easily hidden under carpets or furniture. In addition to the push-button remote, a time-clock remote allowed the owner to program the set to come on at a certain time and tune to a particular station. The time clock utilized the same plug connection as the remote push-button unit. The Robot Control must have sold fairly well, as a fair number of Robot Control receivers exist in collections today.

The Philharmonic, Sixteen/Eighteen and the Autotrope made a tremendous offering for 1937. In spite of a dip in the economy that year, sales remained stable, totaling $780,000. Scott often felt the economic effects in his company a bit later than the rest of the nation, however. This would be seen in the coming year. Even with the introduction of two new receivers, sales would literally plummet in 1938.

Telematic

Scott’s extensive experimentation with remote-control operation gave rise to perhaps the most unique Scott set ever built. The Telematic was
announced in the March, 1938 issue of the *Scott News*. The set was nicknamed the “Modern Aladdin,” and was a totally remote-control set. The Telematic has no dial face, and did not require a cabinet at all. Very few pictures survive of the Telematic; one picture with Mr. Scott and an unidentified gentleman shows a Telematic in a Braemar console, with only the time clock showing on the cabinet face. The *Scott News* article shows many placements with the receiver unit housed in closets or bookshelves, and the speaker hidden strategically in the listening room. It is probably due to these rather unorthodox placements that no Telematic sets are known to exist in contemporary collections.

Almost all the technical details known about this set are from the *Scott News* description and photographs. The set had the patented phonograph-noise suppressor, giving two of the tubes in the 14-tube lineup. The power supply appears to be identical to the Sixteen, with a pair of 5V4 rectifiers and a pair of 6V6 outputs. The RF appears typical, with a single RF stage, probably the same 6U7, 6L7 mixer and 6J5 oscillator as found on the Sixteen. There appear to be three IF tubes, likely two 6K7s and a 6B8, as second detector and IF AVC. This leaves two tubes on the chassis, and they are quite probably the first AF stage and an inverter to drive the final AF stage. Although purely an approximation, these are probably a 6K7 and a 6F8 respectively.

The Telematic was not heavily advertised, since there really was not a “pretty” radio to place in advertising photographs. Several magazines had small ads with the name of the set, and a picture of the remote-
control keyboard. Scott's success with this set is unknown, but no contemporary examples certainly seem to indicate a lack of sales for the Telematic.

**Phantom**

The August, 1938 issue of the *Scott News* features a truly classic photograph of E. H. Scott standing beside his latest creation, the Scott Phantom. It is unclear today whether the set pictured in this issue of the *Scott News* is a prototype. There are several differences, most notably the slide-rule dial face and the picture of the amplifier. The dial face is "reverse" of the typical Phantom dial face (black letters on light background, rather than white letters over black). The power supply pictured clearly shows a 6F5 tube, yet no Phantom schematic exists with this tube in the power supply, and none of these sets are known today. The basic Phantom covered 550 kc to 22 Mc in four bands.

The earliest Phantom diagram (dated October 21, 1938) again resembles the Philharmonic circuit on a smaller scale. The Phantom had a single
Figure 51. Late 1930s cabinet examples. Changing styles moved the larger sets into "side-by-side" cabinets that became very common in the 1940s.
6U7 RF stage, feeding the 6L7 mixer from a 6J5 oscillator. A separate 6B8 provided RF AVC. Three IF stages (all 6K7s) feed signal to a 6H6 second detector. The IF bandwidth is still adjustable, but not continuous. Rather, the Phantom had a three-position switch, to allow “broad,” “medium,” and “sharp” characteristics. The audio section contains the Scott trademark scratch suppressor, using the 6B8 and 6J7 tubes. The first AF stage is a 6K7, followed by a 6J5 inverter. The second and third push-pull AF stages are on the power supply, and include a pair of 6J5 and 6V6 tubes. A tuning eye and two 5V4 rectifier tubes round out the 19-tube version of the Phantom. A revised version of this diagram (dated March 1, 1939) appears in Rider’s as well, but contains few differences. The only real items of interest are that the rectifier tubes are now listed as 5Y3s, and the set shows the optional television band added. For $19.50, the television band would allow reception from 21 MHz to 60 MHz on a single additional band.

By late 1939, about the same time that Scott introduced the upgraded Philharmonic, the Phantom also received many of the same upgrades. The “Deluxe” Phantom is a 20-tube set, adding a voltage regulator on the oscillator. The third IF tube is changed from a 6K7 to a 6B8, which allows it to double as the third IF and the second detector. The original 6H6 is now used as a Dickert noise limiter, just as in the Philharmonic. Finally, the audio amplifier is greatly upgraded, using 5U4 rectifiers, and using a pair of 6L6 tubes for the final output stage. This boosts the output from the original 13.5 watts undistorted output to 35 watts. In
early 1940 the semi-circular logging scale appears on Phantom dials, similar to the Philharmonic. The Deluxe Phantom is truly a first cousin to the famed Philharmonic.

An export version of the Phantom is described in the *Wireless World* dated February 2, 1939. This set, also built by the British licensee, is a unique 16-tube set. The tube lineup is as follows: 6U7 RF, 6L7 mixer, 6B8 RF AVC and a 6C5 oscillator. The first and second IF stages are 6K7s, followed by the 6B8 third IF/second detector. The first AF is a 6K7, and the inverter is another 6C5. A pair of 6C5 tubes is the second stage audio in push-pull, followed by a pair of 6V6 tubes. Two 5Z4 rectifiers and a tuning eye make up the 16-tube complement. The export set also operated on a 470 kc IF, rather than the US standard 455 kc. Without cabinet, the set sold for 36 guineas, comparable to the US price.

The Phantom introduces one new “mystery” into Scott set production. In addition to the usual builder and licensing tags found on all Scott receivers, many Phantom tuner chassis have a tag that state “Model A,” “Model B,” or “Model C.” No “models” higher than C have been reported, and the exact differences that distinguish this nomenclature are unknown. These tags and model designations appear on only one other Scott set, the Masterpiece.

With the introduction of the Phantom in 1938, Scott now had a high-priced set (the Philharmonic) and a mid-priced receiver (the Phantom). The US economy however, had not fully recovered from the depths of the Great Depression. Demand for an inexpensive Scott receiver was very high, and the difference in price between the Sixteen and the Phantom.
Figure 54. Phantom FM chassis. The FM Phantom had to be enlarged to accommodate the FM tuner. Note the non-symmetrical chassis positioning.

was negligible. Sales dropped dramatically in 1938, falling to just $521,000. Scott attributed some of this downturn to greatly reduced advertising in May, June and July of that year. However, this steep drop in sales forced Scott to borrow $100,000 to continue his business. A low-priced set could really do no harm, and might bolster sales in the coming year. Therefore, Scott introduced a new "low end" receiver into his 1939 lineup, the Super XII.

Super XII

Offered at the (for Scott) incredible price of just $99, the Super XII was the smallest Scott receiver offered in almost five years. Giving it an appearance to remind the tight-fisted buyer of the Philharmonic, the Super XII used an "airplane" dial face, rather than the slide-rule dial on the Phantom. The first Super XII sets produced also have the very unique distinction of being the only chrome chassis Scott-sets that are completely self-contained on a single chassis. Scott had always argued that by placing the power transformer and rectifier on a separate chassis, ac hum was kept to a minimum. However, Scott compromised this premise to create the very low-priced Super XII.

The Super XII circuit was certainly a no-frills design. The tube lineup is familiar: 6U7 RF, 6L7 mixer and 6J5 oscillator. The first and second IF stages were two 6K7 tubes, the third IF/second detector is a 6B8. The first AF stage is a 6K7, followed by a 6F8 as the second audio and inverter. A pair of 6V6 tubes is the final AF, and a single 5V4 rectifier and tuning eye tube complete the Super XII. The wavelengths covered are the same as the Phantom: 550 kc to 22 Mc in four bands. The fifth
Figure 55. Super XII receiver. For the poorest of the poor who bought Scott receivers. Selling for as little as $99, the Super XII was not as popular as one might guess.

“television” band, covering up to 60 Mc, was also a $19.50 option on the Super XII.

Whether the chassis-mounted power supply actually caused problems in the Super XII is unclear. However, Scott did not remain with this arrangement for more than a few months. By March, 1939, the Super XII was shipping with the power transformer and rectifier tube on a single, small external chassis. The additional chassis and cable did not come without cost, and the price of the set jumped about $10.

Figure 56. Super XII receiver and power supply. Late versions of the Super XII had a very small external power supply.
Scott was never satisfied with the Super XII, and in a letter to a prospective customer, he stated that the Super XII would be discontinued in July, 1939, after less than a year in production. Scott still needed a "low end" offering, but the recent demise and purchase of the McMurdo-Silver assets allowed Mr. Scott to create a new moderately priced receiver, the Scott Masterpiece.

Masterpiece

Although the Masterpiece carried the famed McMurdo-Silver trade name, the Scott Masterpiece is unlike any of the McMurdo-Silver sets of the same name. In fact, the Scott Masterpiece is really just a Super XII circuit and chassis layout, with the addition of two tubes in the audio stages. Priced near $170, the Masterpiece was still the lowest priced set in the Scott lineup in 1939 (the Deluxe Phantom was selling for $250, and the Philharmonic was over $300).

The tube lineup is typical Scott: 6U7 RF, 6L7 mixer, 6J5 oscillator, two 6K7 IF stages, followed by a 6B8 third IF and second detector combination. The audio stages include a 6K7 first AF, three 6J5 tubes (one inverter and a push-pull second AF stage), and a pair of 6V6 tubes for the final audio. A 5U4 rectifier and the tuning eye round out the 14-tube Masterpiece design. Other than the push-pull second audio stage, this set is effectively the same as the Super XII it replaced. In fact, the schematic indicates that the alignment instructions for the Super XII should be used on the Masterpiece. Frequency coverage is also the same, spanning 550 kc to
22 Mc in four bands. The Television band from 22 to 60 Mc was also available for the Masterpiece.

The Masterpiece leaves contemporary Scott collectors with several mysteries, however. First, virtually every Masterpiece set has an additional metal tag on the chassis, which gives a Model designation of a single letter. Two Masterpiece units in one collection are “Model C” Masterpiece sets. The meaning of the model designations is unknown, and only a single schematic diagram is known for the Masterpiece. The second mystery surrounding the Masterpiece is the FM version of this set, pictured in the March, 1940 Scott News. This set might be a “photo” unit, built up for advertising, but not actually containing any circuitry. This practice was used at the Scott Laboratories, as attested by several former employees. However, the FM service manual provides specifications as to chassis size and layout for the Masterpiece FM. However, none of the FM Masterpiece sets is known today. Finally, we may never know why Mr. Scott offered a set with the same name that his main competitor used for many of the preceding years. It may be that Scott truly wanted to honor Silver’s sets and competition. The reasoning behind the naming of the Scott Masterpiece will forever be an enigma.

The Super XII and the Masterpiece contributed to a slightly improved financial picture for Scott in 1939. Once again, he had curtailed his advertising during traditionally weak sales months (May, June and July). However, sales still rose to $685,000, a dramatic improvement from the previous year.

Special Communications Receiver

The Special Communications receiver is the final new design offered by Scott using the Philharmonic circuitry. The “Special” is perhaps the most sought after Scott receiver outside the Quaranta series. Fewer than ten Specials are known in contemporary collections, and each of the known sets seems to have a story or mystery associated with it. The Specials are the only Scott sets that have a builder tag placed in the center of the front panel. Engraved with the name of the owner, only about half of the existing sets have the original builder tag still attached. The serial numbers for the Specials is also one of the more unique sequences; all known Specials are prefix JJ, with the lowest set being JJ-251, and the highest being JJ-271. Although it is purely conjecture, it seems likely that fewer than a dozen Special Communications receivers were ever assembled.

Although the tube lineup is familiar, nothing else about the Special resembles previous Scott sets. In addition, the Special Communication Receiver has features and functions not found on any other Scott set of
any time period. The Special is really two totally separate tuners built on the same chassis. Both tuners had two stages of tuned RF, providing superb signal-to-noise ratios. All short-wave bands had full band-spread tuning, the IF has three degrees of variable selectivity, and a continuously-variable crystal filter is provided. The Special also offered a BFO, noise limiter, phono-scratch suppressor, antenna compensation, RF gain, AVC cutout, calibrated tuning meter and stabilized oscillator supplies. Requiring 26 tubes, the Special is not the largest Scott receiver. It was one of the more expensive, however, with a list price of $650.

The coverage of the Special is handled across nine bands. The right hand tuner covers just two bands, the long wave from 140 to 395 kc, and the AM band from 520 to 1710 kc. The left tuner is the short wave tuner, covering 1.7 Mc to 64 Mc in seven bands. Each of the tuners has the typical Scott “front end,” comprised of two 6U7 RF stages, a 6L7 mixer and a 6J5 oscillator. The oscillator tubes are fed from a VR-150 regulator. Thus, nine tubes of the twenty-six are devoted solely to the RF stages of the Special. The Special boasts only three IF stages, all 6K7 tubes. A 6B8 follows as the second detector and also functions as the BFO. A separate 6B8 generates all AVC voltages, and a 6H6 functions as a noise limiter. In addition to the scratch suppressor (a 6B8 and a 6J7), the three stages of audio include a 6K7 first stage, a 6J5 inverter, and a pair of 6J5s in push-pull driving a pair of 6L6 output tubes. The remaining tubes are another 6J5 as the tuning meter amplifier and a pair of 5U4 rectifiers. If the audio lineup sounds familiar, it should. The basic design of the Special audio is identical to the Phantom sets, and most of the known Specials have what appear to be unmodified Phantom Deluxe power supply units.
As with most Scott sets, the exact end of production for the Special Communications Receivers is unknown. One story by a former employee tells that a cache of components for building Specials was found either during or just after World War II. Supposedly two or three sets were built with these parts, but no corroborating evidence exists for these sets. Photos exist of a set marked “United States Signal Corps,” but a set with this tag has never been located. One of the most common photos is the set built for E. H. Scott himself. Of the sets with tags, the set marked “New Zealand Legation” also has a hole punched on the chassis for an additional tube just to the right of the crystal filter. The hole is capped,
and the possible use for a 27th tube is unknown. Almost no "factory" data exists for the Specials, and with the exception of an article in *Radio & Television News* in October of 1940, no publication other than the *Scott News* discusses the Special Communications Receiver. Truly one of Mr. Scott's most complex offerings, the Special will remain one of the most desired and unique sets built by the E. H. Scott Radio Laboratories.

**FM Development at the E. H. Scott Radio Laboratories**

In December, 1939, the Scott Radio Laboratories obtained a license to build FM receivers based on the Armstrong licenses. Research began immediately, and by March, 1940, Scott introduced an FM tuner for the 41 to 50 Mc range. This tuner circuit was the last major technological innovation that the company would give to the American public before the United States entered World War II. Credit for this development goes to Marvin Hobbs, who was the chief engineer of the Laboratories during this period. In discussions with Mr. Hobbs regarding the FM development, he described some legal and philosophical opinions on FM circuit design:

“At the time these receivers were developed, a power struggle between RCA and Armstrong had considerable influence on FM receiver design. Both RCA and Hazeltine held large numbers of patents, which covered almost every aspect of radio receiver design. Receiver manufacturers in the USA had to license with them or face lawsuits which would soon close them down. The only defiant company was Zenith, which was willing to commit sufficient resources to fight both RCA and Hazeltine in the courts. They refused to license with them to finally win many years later. The third licenser was Major Armstrong with his FM patents.
Figure 62. FM tuner schematic. Hobb's unique 41-50 MHz FM tuner.

"The result of this conflict was that there were two methods of handling FM signals. One approach used limiters and a discriminator detector, covered by Armstrong's patents. The other approach used no limiters and a ratio detector, which RCA could use to circumvent Armstrong's patents, and which they recommended to their licensees. Hazeltine went along with the RCA approach. At that time, only a few companies, that aspired to higher quality receiver performance, held Armstrong licenses. These included Scott, Zenith and Stromberg-Carlson. Having an Armstrong license at Scott, we could use Armstrong's circuitry, which consisted of limiters and a discriminator detector.

"When I [Marvin Hobbs] went with RCA to develop the Berkshire receiver, I had to use a ratio detector instead of the Armstrong limiter-discriminator approach. These two methods of amplifying and detecting FM signals are in use to this day, not only in the FM band, but also for detecting the sound signals associated with television signals. Ratio detectors are more widely used because they are less expensive and in many instances the designers have no incentive to refine the FM reception. However, a few quality manufacturers continue to use the limiter-discriminator approach."

The Scott FM tuner starts with an 1853 high Gm tube as the RF amplifier. The output is transformer coupled to the mixer, a 6SA7 tube. The triode section of the 6SA7 is used as the local oscillator. Scott apparently was pleased with the performance of the 6SA7, both for its stability as an oscillator and its loading characteristics as a mixer. A VR150 regulator stabilizes the oscillator plate supply, providing a stable IF output at 5.25
Figure 63. FM Tuner in Mode' cabinet. The only cabinet offered specifically for the FM tuner.

Mc. The IF amplification is passed through four stages. The first two stages are type 1232 high Gm tubes. The IF coupling is unique, using a combination of inductive tuning and capacitive coupling to minimize inductive coupling in the IF transformers. The third and fourth stages are generally referred to as the first and second limiters. This function is obtained from two 6J7 tubes, in a cascade limiter circuit. The grid-leak condenser combinations used in these stages determine the noise limiting time constants. The first limiter has a time constant of 2.5 microseconds. The second stage is at half that value. The discriminator/detector is a 6H6 dual diode. With a well-balanced diode pair, the detector circuit should have a uniform response from 30 to 15,000 cycles. The R/C circuit following the diode load is a correction for pre-emphasis of high audio frequencies imposed at the transmitter. Finally, a 6E5 tuning indicator is fed through a voltage divider/audio filter from the second limiter stage.

The stand-alone FM tuner unit has a 5Y3 rectifier for the power supply. All combination sets derived their power from the set supply. According to the service manuals available, the Phantom and Masterpiece sets were widened 3 5/8 inches to accommodate the FM circuit. This created a rather unique, non-symmetrical appearance to these two FM sets. The Philharmonic chassis remained the same size, but the audio stages were rearranged and the volume expander removed to allow for the FM circuit. The FM circuit of the Philharmonic combination also has two 1853 RF amplifier stages, while all other versions used a single RF stage. The development of the FM receiver led Scott to produce one totally new and final set prior to the start of World War II. This was Scott’s first set that was actually designed to be an AM/FM receiver, the Laureate.
During the summer of 1941 the world was beginning to feel the pressure and effect of the war in Europe. With the US role still unclear, the consumer market was actively seeking radio receivers to allow them to follow the situation in Europe. Scott’s new FM circuit design was made available in modified Philharmonic and Phantom sets (and possibly the Masterpiece), but the Scott Laureate holds the distinction of being the first Scott set designed to be an AM/FM receiver. An 18-tube set, the Laureate sold for approximately $250, making it a comparable competitor to the Phantom.

The Laureate competed with the Phantom in appearance as well, with a slide rule dial that looks remarkably similar to the Phantom. However, the Laureate does not have the same coverage as the Phantom Deluxe. The Laureate covers AM and FM, and a single shortwave band from 9.2 to 15.6 Mc. The set is equipped with a phonograph input, and does advertise FM response to 15,000 cps, a better range than allowed by the Philharmonic or Phantom without the purchase of a set of high-frequency speakers and a crossover network.

As a newly designed receiver, the tube complement of the Laureate is quite different from the previous late-1930s sets already discussed. The AM/SW section used a 6SK7 RF, and a combined 7J7 oscillator/mixer tube. The first IF stage is a 6K7, followed by a 6B8 second IΩ,
which doubles as the second detector and AVC. The first AF stage is a 6J5, followed by a 6C8 dual triode as a second AF stage and inverter. This drives the push-pull 6L6 final AF stage. The FM circuit is the same as previously discussed, using a single 1232 RF stage, a 6SA7 oscillator/mixer, and two 1232 tubes as the first two IF stages. Instead of two 6J7 limiter stages, a single limiter stage using a 6SJ7 feeds the 6H6 discriminator. Late versions of the Laureate use an 1853 tube as the FM RF amplifier, and the two IF stages are changed from the 6K7/6B8 combination to a pair of 6AC7 tubes. A tuning eye and a pair of 5U4 rectifiers complete the lineup of the Laureate.

The Laureate offered the calibrated logging scale as an integral part of the tuning dial. Additionally, the power supply of the Laureate is noticeably different from previous Scott power amplifiers. First, only the rectifier tubes are present, the final AF stage is contained on the tuner chassis. Also, almost all known Laureate sets have a flat black power transformer, to better dissipate heat. While it is rare today to find a Scott receiver with a burned out power transformer, the shift to a black unit seems to indicate that failures of this sort were a concern. The Laureate also used a new dual-speaker, with a mounted high-frequency unit in the middle of the low-frequency speaker. This also required a crossover network, which contains a 35Z5 tube. (This is the 18th tube, for those who were counting earlier.) The Laureate represents the latest technological innovations at the E. H. Scott Radio Laboratories prior to World War II. The Laureate (and Philharmonic and Phantom sets) were produced into the war until parts ran out sometime in the summer of 1942.
Tauscher Sound Boards and Speaker Equalization

In 1940, Scott introduced the Tauscher Sound Board as an option for any of the sets of the line. The sound board was based on the work of Mr. Erno Tauscher, who had obtained patents for his design in 1931. The basic premise is that three baffles of various sizes will distribute and "harmonize" the speaker output. The Tauscher board is placed directly in front of the speaker, and in fact come in several sizes. While there would certainly be questions today about placing baffles in front of the speaker systems, in the early days of radio many new ideas were tested. Scott went somewhat beyond the original Tauscher designs, and in 1940, E. H. Scott filed for his own patent on a "Sound Equalizer Reproducer System". Patent #2,271,100 was granted on January 27, 1942. By the time the patent was granted, civilian radio production had ceased, and it is doubtful that any of the Scott designed sound baffles were ever sold.

Scott Serial Numbers

Obtaining an accurate picture of the distribution and use of Scott serial numbers is difficult. No company documentation exists giving any indication of exact production figures. Conversely, a close examination of the serial numbers recorded today doesn’t really provide much insight into the original production figures. However, over the years, many serial numbers have been gathered, and working from a database of approximately 500 serial numbers, a few inferences can be drawn.

First, the Scott serial numbers must be broken into two categories based on the prefix. All Scott serial numbers on the chrome chassis sets from the Allwave Deluxe through the Laureate are of the form: PREFIX-NUMBER, where PREFIX is either one or two letters and NUMBER is
Figure 67. Patent diagrams for Scott's "Sound Equalizer." Scott's own implementation of the Tauscher patent, claiming significant enhancement.
a number greater than 10 and less than 900. If two letters are used, they are the same. Examples of serial numbers are G-242 and AA-589. All sets produced from the Allwave Deluxe (1932) through the first Philharmonic sets (1937) have a single prefix letter. Within each single letter prefix, the sets do appear to have chronological numeric assignments. However, the numbers don’t match up with different prefixes. Just because G-242 is an Allwave Deluxe does not mean that M-242 would also be a Deluxe; it might well be an Allwave 15. Interestingly, the first Philharmonic sets (the ones with single-letter prefixes) are all prefixes D, E or F.

The chart on page 80 summarizes the distribution of serial numbers for the sets with single-letter prefixes (Allwave Deluxe to early Philharmonic). Multiple examples (ranges) of numbers are indicated by “to” within the appropriate boxes. Numbers without a “to” indication are single serial number examples. The Allwave Deluxe sets are split with 1932 given to known early (non-AVC) sets, and the 1933 numbers given to the AVC Deluxe receivers. Similarly, the Allwave 23 is separated into the early and late variations. Once again, the Allwave 23 service manual indicated that all High-Fidelity sets above serial number 500 have the upgraded IF trimmers and other modifications. It is apparent from this table that those changes are present in a majority of the High-Fidelity sets.

At some point in the latter half of the decade, Scott began using the double-letter prefixes. Why this was done is not clear, but it seems to coincide with the selling of more than a single model at the same time. From the introduction of the model Sixteen, and up to World War II, only a few early Philharmonic receivers have single-letter prefixes. All “late” Philharmonic sets (all FM Philharmonics, for example) have double-letter prefixes. Proving that numeric values were chronological within each double-letter prefix is a bit more difficult. One reason is the “blocks” of numbers that appear in the later serial numbers. The Special Communications receivers provide an excellent example. As mentioned previously, all the Specials have prefix JJ. The low set is JJ-251 and the high set is JJ-271. No other sets fall within this range. All the stand-alone FM tuners have prefix HH, as a second example. Finally, sets are interspersed within each prefix: AA-214 might be a Philharmonic, and AA-253 might be a Phantom, followed later in AA by another Philharmonic. This makes set estimations very difficult using these serial numbers. It may be that there is a different significance altogether to the double-letter prefixes.

The War Years and Scott’s Contribution to the Allied Effort

One of the worst hazards for the Allied effort in the early days of World War II was the threat of the German submarine fleet. Equipped with highly sensitive radio direction finders, the German submarine
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The distribution of serial numbers for the Scott radios with single-letter prefixes.
commanders were able to locate military and supply vessels by simply scanning for radio emissions from a receiver being used aboard a ship to obtain news or instructions. These emissions were due to the radiation leaked from the local oscillator of the now omnipresent superheterodyne receiver. Due to the incredible loss of materiel and lives on merchant ships in particular, the Navy requested that all radio manufacturers work to eliminate the problem of oscillator emissions. To that end, Chief Engineer Marvin Hobbs worked throughout early 1942 to create what was dubbed the SLR (Super Low Radiation) receiver design. This research resulted in patent 2,314,309, which was granted on March 16, 1943.

The basic problem to be solved was how to limit the transmitted radiation of the local oscillator back through the antenna circuits. Physically, the SLR sets are different from other contemporary designs, particularly in the "front end" stages of the receivers. While much of the theoretical work behind the SLR receivers was beyond the understanding of the average person, Mr. Scott did write a good layman's description of the problem. The article, "How Ship Receivers Give Away Their Positions," was published in the November, 1942 issue of Radio Craft. The Merchant Marine purchased a truly amazing number of Scott SLR receivers during the War, and almost every Merchant Marine model was also offered in a Navy version.

In addition to the SLR receivers, Scott produced two solely military, ultra-high-frequency receivers as well. In early 1943, the government purchased a number of Scott's new receiver, the RCK. Assigned Navy code CZC-46223, the RCK covered 115-156 Mc, in an eighteen-tube

Figure 68. RBO-2. The RBO family had several variations, differing only slightly in tube lineups.
Figure 69. SLR-F. The Merchant Marine version of the RCH.

Figure 70. RCH. The Navy version of the SLR-F.
Although most Merchant Marine sets had a Navy variant, the SLR-128 is an exception.

A first cousin to the SLR-12B, no Navy version of this set was ever built.
The following year, the RDO made its appearance. The RDO is a far more complex receiver, having separate power supply (CZC-20314), IF/AF (CZC-50198) and preselector (CZC-10369) units to comprise a single receiver. The frequency range of the fourteen-tube RDO was also quite impressive, operating from 40 to 3400 Mc.

The chart on page 85 summarizes much of the information on the World War II Scott receivers.

AR-1

The Scott Model AR-1 is perhaps the most unique Scott set known, because it is certain that only one AR-1 was built. The reason was the application, in that it was the personal radio of the President of the United States, to be used when flying in the newly-christened presidential aircraft. The Scott Model AR-1 is a special seventeen-tube superheterodyne receiver covering the frequency ranges from 150 kc to 23.6 Mc in five bands. Marvin Hobbs developed the set during the autumn of 1943. It was designed for operation in aircraft on a 115V, 400-cycle single-phase ac source and a 24 Vdc supply. The five wave bands covered are 150-400 kc, 540-1550 kc, 1.6-4.3 Mc, 3.5-9.9 Mc and 8.8-23.6 Mc.

Only thirty days were given to develop the set. This was made even more difficult by the fact that neither Marvin Hobbs or E. H. Scott had attempted to build an aircraft receiver before. They decided not to develop a totally new set, but to simply modify the existing marine application designs. In studying the parts list of the AR-1, the use of "off the shelf" components is evident. The short-wave bands and the long-wave band use RF and oscillator coils from the SLR-F receiver. The broadcast coils and the IF transformers are the same part numbers used in the RBO receivers. The power supply was more unique: the 24 Vdc supply fed all the filaments except the rectifier, the third AF stage and the tuning eye. The 115 Vac, 400-cycle supply fed a transformer that provided B+ potential as well as filament voltages for the tubes.

As installed, the set resembled an automobile radio of the period. It used flexible shafts and couplings to operate the receiver from a small control panel in the President's cabin. The set itself rode in a baggage compartment just below the cabin. The total distance between the control panel and the set was less than six feet. The space for the control panel was small, requiring the use of the rather unusual 6AF6 eye tube. This tube did not perform as well as the 6E5, so a 6SJ7 amplifier was used to boost the signal to the eye tube, giving it better action for the user. Even in this small space, the control panel had the tuning indicator, a fidelity control, selectivity, volume, noise limiter and power on-off. The noise limiter switch also operated the A-N Range switch, which allowed the user to filter out the code signals on the long-wave weather-band broadcasts.
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<td>CZC-20314 (P/S)</td>
<td></td>
<td>5U4, 6E5, 6H6, 6J5(2), 6K7, 6SA7, 6SN7, 6V6(2)</td>
</tr>
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<tr>
<td>SLR-H</td>
<td></td>
<td></td>
<td>5U4, 6E5, 6H6, 6J5, 6K7, 6SA7, 6SK7(2), 6SN7(2), 6V6(2),</td>
</tr>
</tbody>
</table>

The Scott World War II receivers.
Figure 73. The AR-1 Control panel. It is possible that Franklin Roosevelt operated these dials.

Figure 74. AR-1 tuner chassis, top view. Held in a hold below the President's cabin, the tuner is built like the SLR receivers it is modeled after.

Figure 75. AR-1 tuner chassis.
The circuit description is given in the instruction manual. The antenna input is coupled to high impedance antenna transformers on all bands. Two tuned RF stages (two 6SK7s) provide the first signal amplification. The output of a separate 6J5 oscillator tube is fed into the 6SA7 mixer. By using a VR-150 voltage regulator and a separate oscillator, a much higher degree of stability was obtained. The IF signal (455 kc) was then fed into a two-stage IF amplifier (two 6SK7s). The second detector was a 6H6, which also doubled as the AVC. A second 6H6 provided a noise limiter stage before entering the AF amplifier circuits. The first audio stage is a 6SK7. The AVC voltage is applied here, realizing a better AVC action. The second AF stage is a 6J5, with a second 6J5 as an inverter to the third AF amp. The final AF stage is a pair of 6V6s in a push-pull configuration. The output was rated 10 watts from 50-15000 cps. The three remaining tubes are the 5U4 rectifier, the 6AF6 eye tube and the 6SJ7 tuning eye amplifier. The receiver chassis measured 19” W x 11” H x 18” D. The aircraft (and its radio) are fully restored and on display at the United States Air Force Museum in Dayton, Ohio.

The Post-War Era and the Departure of E. H. Scott

Over the years, quite a bit of material on E. H. Scott and his company has been written. However, very little information is found on the post-war receivers. This lack of information is partly due to the fact that Scott was no longer affiliated with the company after the summer of 1945. Near the end of the war, Scott traveled again to New Zealand. The trip followed on the heels of a deal made between Mr. Scott and Hal Darr, who had just purchased controlling interest in the E. H. Scott Radio Laboratories. However, when Mr. Scott returned to Chicago, he found that Darr and the officers had issued more than 200,000 shares of public stock, and Scott was no longer president of the company. Scott denounced this move, and took out full-page ads in the major Chicago newspapers. He informed everyone that he was no longer associated with the company. On August 14, 1945, the name of the company was legally changed to Scott Radio Laboratories, Inc. The removal of his initials (E. H.) from the name mark the start of the decline of the company. Ernest and his wife Jessie purchased a home in Saanich, British Columbia and retired. Ernest died on October 27, 1951. Perhaps fortunately, he did not live long enough to see the final demise of the great company that he started.
Undoubtedly the best known post-war Scott receiver is the 800B. This set, first offered in 1946, is usually considered the last of the “classic” sets by most Scott collectors. Designed by chief engineer Marvin Hobbs, the 800B is a fine set, with motor-driven, push-button tuning. The set employs 24 tubes, and covers AM, modern (88-108 Mc) FM, and the short waves from 5.9 to 18.2 Mc. If the 800B wasn’t large enough for the average homeowner, Scott later sold the 800BT, which was an 800B with a built-in projection television. This is a set that absolutely requires disassembly before moving! Due to the size and price, only a few examples of the 800BT remain in collections today.

Technically, the 800B was advanced for its day. The set offered sensitivity and selectivity controls similar to the pre-war sets. Separate base and treble controls allowed excellent audio response, and a powerful coaxial speaker, driven by push-pull 6L6 output tubes created a rich sound in a monophonic receiver. The AM/SW section of the 800B was comprised of the following: 6SK7 RF amplifier, separate 6J5 oscillator, 6SA7 mixer, two 6SK7 IF stages, a 6H6 second detector and a 6E5 tuning indicator. The FM portion of the receiver consisted of a 6AG5 RF amplifier, 6C4 oscillator, another 6AG5 as a mixer, two 6AC7 tubes as first and second IF stages, followed by two 6SJ7 limiters, a 6H6 discriminator and another 6E5 for FM tuning indication. The audio section

Figure 77. The 800BT Radio/TV combination. A very expensive set in its day, few examples survive in collections.
Figure 78. Scott Video receiver (model 13A). Not a complete television, the 13A is an outboard TV receiver.

Figure 79. Possible prototype set or, post-war chassis "re-use" in home application.
uses 6J5 tubes for the first two audio stages, followed by a 6SL7 inverter feeding the two 6L6 output tubes. A pair of 5Y3 rectifiers and a 0D3 (VR-150) voltage regulator provides power for the set.

**Other 1940 Scott Radio Laboratories Products**

The late 1940s provide us with two more Scott "mysteries." One such, introduced in late 1946, is the "Scott Video Receiver." The set looks like a typical console TV of the period, but is not a complete set. Rather, it is an outboard television receiver and it required connection to a Scott (or other) radio for audio amplification. It was a large set, using 32 tubes, including a 12JP4 picture tube. It also included an audio tuner for the modern FM band. The set covers early VHF (1-13) channels. In addition, the 13A was a receiver for FM (88-108 Mc), and 108-174 Mc, which covered amateur, aviation and some government traffic. No examples of this unit are known today. The set appears in Rider's TV-1 as the model 13-A, and a Scott factory service manual was located about a year ago. It is certainly possible that some of these sets are still around.

The second mystery is obviously an attempt to utilize an excess of military receivers that were built but not sold to the government. At least one example exists of a set with the tube lineup and chassis layout of the SLRM radio. The front of the set is very different, however, with a large glass "slide rule" dial and knobs similar to the 8008. The set also has an extra SW band, giving it AM and SW coverage from 3.5 to 23 Mc. Unfortunately, the one known example of this set, while in a cabinet, has no model indication.

In 1947, the Scott Export receiver was announced. The Export was a much smaller, twelve-tube set. It covered AM, and short wave from 3.2 to 23.5 Mc in four bands. The RF is an older 6K7, the oscillator is a 12J5 and the mixer is a 12SA7. This is followed by two 12SK7 tubes as the IF stages. A 12H6 second detector drives two stages of audio (both 12SN7 tubes). The final AF is a pair of 25L6 tubes in push-pull. Because the set is an ac/dc design without a power transformer, the set uses a 25Z6 rectifier. The Export is also one of the first Scott sets to use a permanent-magnet speaker.

Late in 1947, the Metropolitan 16A was announced. This is probably the second most common of the post-war sets, and could almost be listed as one of the Scott "classics." Interestingly enough, the Metropolitan began with a different name. One set that was apparently purchased quite early has a manual that was written for the "Laureate 600B." It is almost certain that the Laureate name created confusion with the pre-war set of the same name. It isn't clear why the 600B was dropped, however.
Figure 80. Metropolitan 16A. A popular and common set, the 16A uses the dynamic noise-suppressor circuit designed by H. H. Scott.

Figure 81. Musicale amplifier. A separate amplifier incorporating the H. H. Scott Dynamic Noise Suppressor circuit.

Figure 82. Noise suppressor (left) and FM converter (right). The FM converter is not marked with the Scott name, and is often overlooked.
A large, two-chassis set, the Metropolitan 16A employs 28 tubes. However, it covers only AM and FM bands. The tube lineup includes an AM section of a 6SK7 RF amplifier, 6SA7 oscillator/mixer, a 6SG7 IF stage and a 6H6 second detector. The FM tuner consists of a 6AU6 RF amplifier, 6C4 oscillator, a 6AG5 mixer, and a pair of 6SG7 IF stages, followed by two 6SH7 limiters. The audio stages included the circuitry of an improved noise-suppression system, including two 6SG7 treble controls, a 6SJ7 bass gate and a 6SJ7 microphone amplifier. Final audio was provided by four stages, including a 6SJ7, a 6SL7, a pair of 6J5 tubes and finally a pair of 6L6 outputs. A pair of 5U4 rectifiers, a 0D3 (VR-150) regulator and a 6E5 tuning eye rounds out the tube complement.

There are three other items marketed in the 1940s that are worth noting. The Musicale is a fourteen-tube phonograph amplifier only. A two-chassis unit, the audio section consists of a 6B8, three 6SG7 tubes, two 6SJ7 tubes, a 6SL7 and a 6J5 to drive the output. The power supply/output chassis has a 6J5 driver, and a 6SN7 phase inverter to drive a pair of 6L6 output tubes. A pair of 5Y3 rectifiers provides dc voltage for both chassis. Another sought-after piece is the modern FM (88-108 Mc) to old FM (41-50 Mc) converter. This unit is a small (7.5” x 3” x 2.5”) unit using three Western Electric 717A tubes. It is a difficult item to spot at a meet, since there is no Scott name on the unit. Data on the converter can be found in Rider’s volume 15.

The last item is a phonograph Noise Suppressor. This uses four tubes, including a 6B8 AF amplifier, two 6SG7 tubes as treble gates, and a 6SJ7 bass gate. The notable item on the noise suppressor is found on the label: “Precision built by Scott Radio Laboratories Inc. Licensed under Hermon Hosmer Scott Patents Pending.” The noise suppressor is the only item known that connects the E. H. Scott company with the later H. H. Scott company. This same circuit is used in the Metropolitan 16A and the Musicale chassis.
The only other 1940s television (other than the 13A and the 800BT) was the 1948 6T11. The 6T11 was basically the same television in the 800BT. The projection television was repackaged into a table top set, using 31 tubes. It tuned the VHF channels (2-13); the picture tube used was the 3NP4. Outsourcing of key components was now fully developed at Scott Radio Laboratories, and the 6T11 can be found with either Sarkes-Tarzian or General Instrument tuners. Further data on the 6T11 can be found in Rider’s TV-2.

The decade of 1950 and the closing of Scott Radio Laboratories

The decade of 1950 saw the demise of the Scott Radio Laboratories, Inc. In April of 1950, the John Meek company announced the intended purchase of Scott. On October 15, 1951, the purchase was official. Meek also moved the company from the famed Ravenswood Avenue address to Plymouth, Indiana. The company would remain there until August, 1956, when the company was forced to declare final bankruptcy. On October 31, 1956, just five years after Ernest’s death, the remaining assets of the company were sold, marking the end of the Scott Radio Laboratories, Inc. During the 1950s about a dozen different receivers were sold, and several televisions.

All of the 1950s radios (and 1940 post-war sets too, for that matter) have the same “look” about them. All have a slide rule dial, with the control knobs located in a row below the tuning scale. Most are two-chassis units, although some of the smaller sets are single chassis. All included the regular AM band and either the modern FM band or some SW bands. None had AM, FM and SW. With few exceptions, data on all these sets can be found in various Sam’s folders. Generally, these sets are not easy to find. Gathering a complete collection of the 1950’s Scott sets would be a serious challenge to the contemporary collector.

The first 1950s set is probably the model 510. It is a simple fourteen-tube set, but it does use 6L6 outputs. There are two chassis, and coverage
is AM and FM only. A new Scott television appears next. This TV is listed in Sam's as the model 710, 910 and the "Ravenswood." It is a 21-tube set, using a 16KP4 picture tube, and tunes the VHF (2-13) channels. The model 310 radio came out in late 1951. It is very similar to the 510, but used only twelve tubes, including 6V6 outputs, on a single chassis. Late in 1950, Scott offered the model 100 "power amplifier". The amplifier is comprised of five tubes including a 6SQ7, a 6SN7, a pair of 6V6 tubes and a 5Y3 rectifier.

**Figure 85. Model 510.**

The year 1952 was probably the last "busy" (and profitable) year at the Scott Radio Laboratories. Three radios and several TVs were announced. The first was the 515 radio. Making its debut in the first half of 1952, this receiver is notable by marking a return to short wave reception. In addition to AM, the set tuned two short wave bands covering 2 to 18 Mc. It did not offer FM, however. The set used twelve tubes, including 6L6 outputs. The next 1952 receiver was the model 1000. A 16-tube set on two chassis, it tuned only AM and FM bands. The 1000 did have a sensitivity control and a tuning eye, two items not found on a Scott

**Figure 86. Model 310**
Figure 87. Model 515.

Figure 88. Model 1000.

Figure 89. Model 1510.
Figure 90. Ashby combination. Early radio/TV combinations were expensive but quite popular.

Figure 91. Kensington combination. The large size of combination sets has left very few of these surviving in contemporary collections.
Figure 92. Model 2000.

Figure 93. Model 2510.

Figure 94. Model 9052.
receiver since the Metropolitan. The 1510 came out late in 1952. It is a fourteen-tube set, and is a slightly modified 510. Scott also offered another audio amplifier around this time. Dubbed the 6001 series, the amplifier was a two-chassis affair, with the pre-amp circuits using a 6SC7, a 6SQ7 and a 6SN7 on one chassis. The other chassis was the power supply/final amplifier, using a 6SN7 phase inverter to drive a pair of 6L6 outputs. A 5U4 rectifier completed the 6001.

Several televisions were offered in 1952. Generally, Scott offered 17-, 20- and 24-inch television chassis. The model numbers (924, 820 or 817) indicate the picture tube size. Dates of introduction for the television sets are not known. All sets covered channels 2-13. Many of the radio receivers were offered in a combination with a television. In the model 1000 "Chippendale," for example, the 24-inch television was combined with the model 1000 radio. The total package cost a hefty $1595 suggested retail. For those with a smaller budget, the "Ashby" combination included a 20-inch television and the model 510 tuner, for a mere $895.

In early 1954, two new receivers appeared. The first was the model 2000. The 2000 had fourteen tubes, and tuned AM and two short wave bands covering 2 to 20 Mc. A larger than average (for this period) two-chassis set, it also returned to the 6L6 output tube for audio quality. The next receiver was the 2510. The 2510 is similar to the 510 and 1510 in appearance, but rather than an AM/FM tuner, it is an AM/SW tuner. Like the 2000, it covered AM and short wave from 2 to 20 Mc. The 2510 used twelve tubes, including push-pull 6L6 outputs. It is unclear why so many short wave sets were offered at this time, when FM tuners were certainly more popular. It may be that Meek was hoping to tap a vertical market, but a high-end short-wave receiver was not well received by the American public. Sales of these sets were disappointing, and from 1954 to 1955 Scott sales declined from $2.1 million to just under $900,000. This resulted in a net loss of just under $200,000, and sounded the death knell of Scott Radio Laboratories.

In 1954, Scott television sets were updated to include the new UHF channels 14-83. Only one radio chassis appeared in 1954, and it is a disappointing little set. A seven-tube, single-chassis set, the model 9052 is a simple AM-only receiver. It is an ac/dc design, using a 117Z6 rectifier and push-pull 35L6 outputs, truly a far cry from the quality and commitment demonstrated in the Allwave and Philharmonic sets twenty years previous. The failure of the company becomes obvious when looking at a set of this caliber. The year 1955 saw a slight improvement, with the introduction of the Model 2100 receiver. The 2100 is a fourteen-tube, two-chassis set, again with AM and SW coverage (2 to 20 Mc) only. The following chart summarizes the models, wavebands and tube lineups of the post-war radio sets described previously.
Early in 1956, John Meek decided it was time to let the Scott Radio Laboratories go peacefully. He sold his holdings to a west coast consortium, the Monogram Manufacturing Company of Culver City, California. By September, 1956, what was left of Scott’s company was placed in receivership, and a receiver’s sale was held on October 30 and 31, 1956. The Scott name, (officially, “Successors to Scott Radio Laboratories, Inc.”) was sold to a group of investors who also owned the Liberty Music Shops. Liberty Music was a large radio and television outlet in the New York City area. Liberty produced a few sets bearing the Scott name and the trademark music note symbol found on the 8008 and other post war sets. Liberty also advertised Scott as “The Oldest Name in Hi-Fi.” With some legal maneuvering, a new corporation in Annapolis, Maryland continued to market the original Scott Radio Laboratories name. Although none of these companies offered any sets worthy of note, all were hoping to capitalize on the name recognition.

In the latter half of the 1950s, the H. H. Scott company began marketing a line of high-fidelity receivers, turntables and amplifiers. Founded by
Hermon Hosmer Scott (no relation to E. H. Scott or his family), the H. H. Scott company was not a descendant of the Scott Radio Laboratories of Chicago. However, the H. H. Scott product line was confused by consumers with the earlier Scott receivers. To avoid further confusion, H. H. Scott filed suit against those using (or abusing) the original Scott name. On June 16, 1961, H. H. Scott won his battle to stop the other organizations from using the Scott name. With that action, it can reasonably be stated that the original Scott Radio Laboratories was gone forever.

**POSTSCRIPT**

The legacy that Ernest Humphrey Scott left the world can be seen in the polished chrome of any of the great receivers. Many of his designs and basic principles survive today. E. H. Scott radios have been discussed in modern magazines outside the antique hobby. Many non-radio people still remember the Scott sets of the 1930s, and all those who find one today can still appreciate the workmanship and quality present in his sets. There is little doubt that Scott will be remembered well into the next century and beyond, for there is truth in his statement that “The Fine Things are Always Hand Made.”

**Author’s Note:** Due to the wide variety of sources of information about Scott and his radios, I cannot even begin to make a claim that this represents a complete list of all Scott sets or variations on the sets. Mostly, this paper represents years of research, notes, and a bit of luck to compile this information. I offer it to readers for what it is...the information known as of this writing. Something new may be learned tomorrow, and undoubtedly, many facts will surface in the coming years.

I owe thanks to many people for much of the data presented in this article. This effort would not have been possible without the assistance and resources of Jim Clark, Marvin Hobbs, and John Meredith. And a special thanks to my family for the many hours I spent researching and writing. Finally, for those that are inspired by this material, for more information please contact the E. H. Scott Historical Society, Inc. As a founder of this organization, I can promise that we will endeavor to provide whatever information and knowledge we can.

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Letter from E. H. Scott to C. N. Robeson, July 10, 1939
Correspondence with Marvin Hobbs, November, 1992
Kent's interest in antique radios goes back twenty years to a few tubes and parts that an aunt gave to him. Reading Jim Fred's Antique Radio Corner in Elementary Electronics ignited his hobby. After joining AWA, ARCA, IHRS and the Michigan Antique Radio Club in the early 1980s, his collection grew to several hundred radios. Ten years ago, the focus became only Scott radios, especially examples of different versions of the same set. In addition to Scott radios, Kent maintains an extensive radio magazine collection and a number of late 30s Supreme test instruments.

Kent is a co-founder of the E. H. Scott Historical Society, and is the librarian and editor of the Scott News, the newsletter of EHSHS. When not restoring or researching Scott radios and their history, Kent is the manager of network security for a large Internet service provider. He has a Bachelor's degree in Computer Science from the Ohio State University College of Engineering, with a minor in Electrical Engineering. Kent lives near Columbus, Ohio with his wife Michele, and his sons Matthew, Ryan and Michael.
The cover of Western Electric News for February, 1919. It depicts two-way air/ground radio communication. Note the trailing antenna on the lead aircraft. (Original in color.)
THE BEGINNINGS OF VACUUM TUBE RADIO
AT WESTERN ELECTRIC

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Historical Interest Group

The vacuum tube changed wireless radically after 1914, opening a new era which lasted until well after World War II. Many of the new developments originated in the Research Branch of the Western Electric Company at 463 West St., New York. Here men with familiar names like Colpitts, Hartley and Heising devised most of the basic circuits used in radio. It is remarkable that so much of the early technology emerged from a company which had not previously been active in wireless communications. This is the story of those new beginnings, told mostly by the men who were there at the time.

Background

The series of commercial companies which exploited Alexander Graham Bell's inventions after 1875 went through several name changes, and the Bell Telephone Company is used here to identify them all. Holding patent rights to the most important elements of the telephone, the company prospered and was able to maintain a strong but by no means impregnable position in this developing market. In 1878 the company was fortunate to gain Theodore N. Vail as General Manager (Fig. 1). It was largely he who guided the Bell company into a much stronger position.

Vail realized that when these basic patents expired in the 1890s the company would be thrown into direct competition with the growing number of independents and that they needed to strengthen their foundations before this happened. He sought to consolidate their position by establishing top-class research and development facilities. His strategy included taking over Western Electric, one of the larger telephone equipment manufacturers, but perhaps his most astute move was to promote long-distance telephony. At a time when there were few connections between towns Vail foresaw that the company controlling these links would be able to dominate the market.

For convenience in raising capital the American Telephone and Telegraph Company was established in New York in 1885 to take on the long distance communication side of the company's business. A.T. & T. eventually became the parent company of the Bell system at the end of 1899.

John J. Carty (Fig. 2) started in the company as a boy switchboard operator and worked his way up to become Chief Engineer of A.T. & T.
in 1907. Carty was particularly active in implementing Vail’s desire for more and better long-distance services.

As their understanding of line transmission principles progressed, ever increasing distances became possible. Inductive loading made it possible to link Chicago with New York and by 1911, using loaded 0.165-inch diameter conductors, they reached Denver. Even this remarkable achievement was short of the desired “coast to coast” objective, and it became evident that the next step would require amplification.

Late in 1909, during talks with the management of the Panama-Pacific Exposition scheduled to open in San Francisco in 1914, Vail & Carty virtually promised that they would have a telephone working between
New York and San Francisco. On their return to New York it is said that Vail told his engineers "We've promised it; now you find a way to do it" (9).

In the potent research laboratories of the Western Electric Company at 463 West St., New York efforts were being made to find a suitable amplifier. In 1903 H. E. Shreeve, of the mechanical department, coupled an electromagnetic receiver directly to a carbon microphone transmitter and succeeded in amplifying an input signal. However, there was so much distortion that few could be connected in tandem. Harold deForest Arnold had developed mercury-arc discharge tubes controlled by transverse magnetic fields which were capable of amplification, but these required expert attention and were not suitable for use in the field. In October, 1912 John Stone Stone and Lee de Forest demonstrated the Audion to Western Electric engineers. This was the second time it had been shown to them, but on this occasion Arnold recognized the inherent possibilities in the crude device. Lee de Forest was paid $50,000 by Western Electric for the rights to use the Audion for telephony, and they started development work to make it suitable as a line amplifier.

By July, 1914 they were able to demonstrate the transcontinental telephone line promised by Vail. Three circuits were installed, one using the Shreeve mechanical amplifier, a second with Arnold's mercury-arc amplifiers, and the third with the vacuum tubes developed from the Audion. All three circuits worked, but the vacuum tube won the contest (3). At the official opening, Alexander Bell in New York spoke to Thomas Watson in San Francisco, repeating his well-known statement, "Mr. Watson, come here, I want you", to which Watson replied, "It would take a week to get there now!" (Fig. 3).
Figure 4. Experimental two-channel carrier telephone system tested by Heising in 1914.

The Telephone Flirts With Wireless

Having reached the goal of “coast-to-coast” telephony the company looked at the next hurdle — how to cross the Atlantic? The telegraph had already shown that it was possible to operate a cable laid under the sea but it was quite clear that this would not be suitable for telephony. By then transatlantic-wireless telegraphy was routine, and radio seemed to offer the best means of reaching the telephone systems of other continents. Attempts already had been made by several workers to transmit speech and music by modulating steady radio-frequency generators, such as the Poulsen Arc and the Alexanderson generator. The company had actually come close to entering into an agreement with R. A. Fessenden to exploit his modulated machine alternator, but the financial panic of 1907 made them withdraw from negotiations.

George O. Squiers, who rose to the rank of Major General as the Chief Signal Officer of the US Army, had been looking into high-frequency communication over telephone wires to increase the number of circuits on each pair and also to increase secrecy. Western Electric had taken an interest in Squiers’ work and had provided some of the equipment.

At the age of 26, R. A. Heising started at Western Electric in July, 1914. He began by making the first experiments on line-carrier telephony using vacuum tubes. Refer to Fig. 4, and note that the modulator is
referred to as a “repeater” in conformity with the usage of the time. R. V. L. Hartley explained the idea of “sidebands” to him, and although Heising was not sure who had conceived the notion he believed that it had been hatched within the Western Electric laboratories. To quote Heising:

“The knowledge of sidebands seems to have been generally confined to our engineers for some time. As much as two years after my introduction to sidebands their presence was not known by all prominent outside radio engineers as I learned by observation, but was generally spreading. When this country entered the war and we helped educate army and navy men in radio we had to point out the sidebands even in the case of their expert radio aids” (2).

Heising was probably the first to use the word “modulation” in the telephone/radio sense.

The potential of the vacuum tube was already well established within the company. Several important basic circuits had been developed and patented, including the push-pull amplifier by Edwin H. Colpitts in 1912, and a stable vacuum-tube oscillator using a tapped-tuned inductor by Ralph V. L. Hartley in August, 1914. Soon afterwards Colpitts had devised its capacitive equivalent.

The Vacuum Tube Telephony Transmitter

Western Electric management now believed that a high-power vacuum-tube telephony transmitter should be possible, and by the end of 1914 it was decided that Hartley’s group should develop a prototype.

Heising was given the job of investigating parallel operation of existing telephone-repeater tubes to see whether it was possible to multiply their output power. By the time he had four connected in parallel in an amplifier circuit he was faced with “singing,” but found that this could be stopped by putting resistances in the grid connections. He was able to get about 1.5 watts from the combination, which was about four times the output from a single tube; this encouraged him to believe that larger powers could be achieved in this way.

A group under H. D. Arnold started work on a large vacuum tube capable of dissipating about 25 watts (to be known as the type W or 204B - see Fig. 5). Hendrik J. van der Bijl determined the electrode sizes and dispositions while Arnold and Weinhart did the mechanical design and construction. This tube was characterized by its anode, which was formed by bending nichrome tape back and forth to form two plates (as proposed by Arnold) which could be heated by an electric current.
during the exhausting process to help remove occluded gases. The filament was made of platinum ribbon coated with barium and strontium compounds and strung across a tall rectangular glass frame (developed by A.M. Nicolson). There were three sections, each in the form of an N, connected in parallel. This resulted in nine lengths of filament, zig-zagging from top to bottom (2).

At that time amplifiers were operated under what was later to be described as class-A conditions (Heising's class C amplifier came later in 1916). Heising tried resistance coupling the RF-power-amplifier stages but soon found that there was little gain due to the high shunt capacitances. He tried tuned-circuit coupling and encountered "singing," which he was able to control only with difficulty.

Heising makes the point that components were expensive in those days, and the need for every tuning capacitor in a circuit had to be weighed against its cost — each crude "Blitzen" or "Mascot" 750 pF variable condenser cost $5.00, and a Marconi 10,000 pF variable with rubber dielectric cost between $25 and $50 each.

The early radio-telephony experimenters had generally modulated the radio-frequency carrier by absorbing part of its energy in a microphone (variable resistance) connected in series with the antenna. In May, 1914 Colpitts patented a grid-modulated oscillator for amplitude-modulated transmission, and van der Bijl later developed the grid-modulated amplifier (patented in August, 1915) which was used during these tests. At this time low-level modulation, followed by linear RF-power amplification, seemed a natural choice.

The Montauk Point Transmitter

It was decided to use eighteen power tubes in parallel to produce an output power of about 150 watts. The drive voltage for the output amplifiers was sufficient to make the grids conduct during part of the cycle. As a result the grid-bias battery voltage rose to about 2 V/cell, and had to be normalized by shunting the battery with a leak resistance. They had numerous difficulties due to the long interconnecting leads which had sufficient inductance to provoke "singing." Sorting the problems out
was complicated by the fact that the handmade power tubes were scarce, and they had to take care not to overload them.

The transmitter was to be installed at Montauk Point (at the extreme north-eastern end of Long Island), favored presumably because of its proximity to New York and because it was almost surrounded by sea. A receiving site was found at Wilmington, Delaware, in the Dupont building (about 250 miles away) on the top of which was a suitable antenna.

A 25-foot square timber frame building was erected (Fig. 6) to house the transmitting equipment, together with a nearby shack for three engine-driven dc generators, providing 110 V for lighting, etc., 500 V for the power amplifier anode supply, and a low voltage for the filaments. Two 165-foot high steel towers, erected 300 feet apart, supported the antenna.

The transmitter circuit, as recollected and drawn by Heising in 1938, is reproduced in Fig. 7. Except for the power amplifier the apparatus was constructed in four boxes, as seen in Fig. 8. The Hartley oscillator mounted in the top right hand box used a low-power telephone-type tube.
The van der Bijl modulator (grid modulation) in the lower right case used a single power tube, which can be seen lying on its side above the plate load coil. The first stage linear amplifier in the top left box also used a single power tube lying on its side. The lower left box "...has a tuned circuit and certain controlling resistances which enter into the transmission system." (1)

The eighteen type-W power-amplifier tubes can be seen lying horizontally in the rack on the extreme left side of Fig. 9. The power tubes in these early tests had no bases and were wired directly into circuit. The oscillator, modulator and amplifier stages drew their anode supplies from batteries of "No. 6 dry cells of which several barrels were used." (2)

Preparations on site progressed according to plan until early in May, 1915 when it was heard that Dr. Irving Langmuir was due to deliver a paper to the Radio Institute on 7 April, and it was thought that this might deal with radio telephony.

"In order that it could not be said that anything Langmuir disclosed at this meeting was instrumental in assisting or contributing to the success of our tests, we had to speed up our preparations." (2)

By 23 March they succeeded in delivering 160 watts into a dummy antenna in the laboratory and had installed the equipment on site by 1 April. The power-supply engine gave some trouble and on 3 April a sleet storm brought down the antenna and the telephone lines.

Carty had already arranged for a party including Prof. R.A. Millikan, Col. S. Reber, F.B. Jewett and B. Gherardi to assemble in New York and travel to Montauk Point on Sunday, 4 April. The antenna could not be raised as the cable passing over the top of the tower had slipped off its sheave and was jammed. In freezing weather Lloyd Espenschied risked his life to climb up the tower on steps, (which had been put on upside down) to rectify the problem.
That evening they were able to transmit telegraph signals to Wilmington with reception confirmed by telephone. At this point "Mr. Arnold took possession of all microphones so that no telephonic words could be transmitted until Mr. Jewett or Mr. Carty had been first in this respect." (2)

Tests were made with one to eighteen power tubes to determine the effects of varying the power output. The antenna current with all eighteen tubes, at about 170 kHz, was four amperes C.W. and six amperes fully modulated. Full power was not achievable, as the anode-supply voltage had to be limited to about 430 V to avoid having the tubes break down.

The visitors were able to talk to Hartley at Wilmington with their words repeated back to them via a third party over the telephone. The line was then connected to the output of the receiver at Wilmington so that listeners at Montauk could hear the quality of reception. The process was then reversed using the telephone line to modulate the Montauk transmitter so that those at Wilmington could hear themselves transmitted from Montauk. The official party then moved to the receiving station where similar tests were repeated.

Several of the development team attended the talk given by Langmuir at the I.R.E., almost entirely devoted to tubes and theories. Langmuir concluded with some remarks on work he had done using a vacuum tube as a power oscillator with a second tube to modulate the output, but disclosed no details. The Western Electric team concluded that in this sphere they were well ahead of General Electric.

Transatlantic Radio Telephony

Carty was now determined to demonstrate that wireless was suitable to extend the telephone across the Atlantic, and a conference in his New York office was arranged to discuss the details. It was already evident that much more power would be required, but it was believed that this could be achieved by connecting an even larger number of tubes in parallel. A longer wavelength would be required to reach around the earth's curvature, and this demanded a much bigger antenna than that used at Montauk.
Point. The Arlington naval radio station had one of the largest antennae in the country (600 feet high...see Fig. 10) and Carty hoped to persuade the U.S. Navy to let them use it for these tests.

Before committing themselves the navy wanted to be assured that the tests would be worthwhile, and a demonstration of the Montauk equipment was arranged for 3 and 4 May, 1915. Captain Bullard and Cmdr. Hepburn of the Bureau of Steam Engineering came up to observe the tests, but said nothing. In Heising's own words,

“Captain Bullard told me later that year that he had no faith in our being able to talk across the Atlantic when the subject was first broached to him. He felt it was the idea of people who knew nothing of radio. He didn’t expect telephone people, of all people, to be able to do it. It was only the fact that the engineers who approached him had unquestioned reputations in the engineering world that prevented him from throwing them out and dismissing the proposal from his mind. He therefore listened politely to what they had to say and witnessed the tests without being convinced. They seemed to be so enthusiastic about the project, however, that he finally thought that as it was their own money they wanted to spend they should be given whatever opportunity there was and he would look into the matter further. And so we were definitely launched on the transoceanic experiments.” (2)

It was decided to try extended distance tests from Montauk Point, and a receiving station was set up at St. Simon’s Island on the southern coast of Georgia. The distance would thus be increased to almost 1,000 miles, besides which it was a good location to bring visitors who could

Figure 10. The 600-foot masts at Arlington (1915).
stay on nearby Jekyll Island where some of the top executives, including Vail, kept winter residences. Spliced wooden 120-foot poles were brought in and erected to support the receiving antenna. By now several of the power tubes had failed and they had to do the best they could with twelve to fourteen. Fortunately these could all withstand 600 V and they were able to get through. Lloyd Espenschied reported as follows:

"After listening a number of weeks to determine the best hours for reception, success was attained and there was heard through the static the human voice which had been spread so thinly on the ether at Montauk Point. Again, for the sake of completeness, the received voice was put on a telephone line and transmitted to other listeners in New York. Again, voices could be heard, but much patience was required in waiting for some brief lull amid June’s troublesome atmospheric noises.” (3)

The Arlington Transmitter

A timber-framed building was erected next to the Government radio station (Figs. 11 and 12). The Navy agreed to allow their 600 Vdc supply to be extended to a local switch board so that they could regulate the generator during tests. They anticipated having at least 500 power
tubes in parallel to reach the desired output power. With each nine-volt filament drawing 4.8 - 5 amperes (Tyne states 4 - 4.5 amperes) the only economical means of supplying so much current was to use an ac supply with a transformer mounted close to the power racks. Heising investigated various ways to minimize the injection of hum from the filaments, and patented the balanced-filament supply which was used at Arlington (U.S. patent 1,432,022).

The design of the transmitter fell largely upon Heising, and the circuit diagram which he reproduced in 1930 is shown in Fig. 13. He decided that the best way of dealing with the enormous number of tubes would be to mount them horizontally, in much the same way as at Montauk, but with ten racks each carrying fifty tubes. As each of these would have to dissipate about 4 kW, cooling fans were required to remove the heat. Separate circuit breakers and the 600-volt commutator noise filters were fitted to each rack.

The early stages were mounted in separate boxes with the oscillator and modulator screened on five sides to avoid feedback from the antenna. The Hartley oscillator with its type-M tube occupied the top section of Fig. 14 - its dedicated anode and filament batteries were housed externally. The speech amplifier can be seen in the center compartment, with its associated input transformer, changeover switch and audio oscillator in the lower part. The modulator can be seen on the right hand side of Fig. 15. The anode tuning coil is immediately below the tube and the box at the bottom contained the grid bias battery. The bases of the first amplifier tubes can be seen in Fig. 15, with six in the lower and six in the upper
boxes. Between two and twelve tubes were connected, depending on the frequency and the number of output amplifier tubes in use.

Fig. 16 shows the “front” of the first five racks of power tubes; the unbased tubes were inserted from the rear and the leads passed through the panel and connected to binding posts or Fahenstock clips. Each tube had its own 2/3-ohm filament rheostat (the porcelain discs), and anode and filament jacks for measuring the current. A grasshopper fuse was
Figure 16. The first five racks of power tubes. The tubes on this rack had no bases and were supported on the other side of the panel with their leads brought through to connectors. The rectangular porcelain blocks between each second row of filament rheostats were the grid grasshopper-fuse blocks. The board between the first and second racks was the distributing rack which held most of the common equipment. The RF input leads came in on the horizontal board at the top of the second rack. The distributing frame is mounted between the first and second racks. Each tube had a pair of jacks to facilitate filament and anode current measurements.
Figure 17. The rear of the first five racks on the right side, and the front of the second row on the left. The RF connecting leads can be seen overhead. The first three racks in the second row held power tubes fitted with bases.

included in each grid connection (the rectangular porcelain blocks) so that in the event of a contact between the filament and grid the fuse would blow, giving a visible indication of the faulty tube and preventing a drop in the bias supply, which would have caused overheating in the other healthy tubes. The anode supply was brought in at the base of each rack and had its own switch, circuit breaker, and ripple filter. The RF input leads came in on the horizontal beam, seen crossing the top of the picture, and were connected individually to each power rack via the terminal strip seen just beneath the beam, and mounted at the top of the white board. The white distributing rack held bypassing condensers, the center-tapped choke for the filament-ground point, and part of the input-tuning capacity, and served all racks.

Fig. 17 shows the rear of the first five racks on the right side, and the front of the second five racks on the left. The first three racks of the second row used mounted tubes and had a different component layout. The output from each rack was taken overhead with individual leads to the combiner at the distribution rack in the first row, and from there by means of a single lead to the antenna transformer.

The antenna transformer, mounted in the attic (Fig. 18), was made by Carl Englund and consisted of a fixed antenna coil (about 25 turns) of copper strap wound on a wooden form about four feet in diameter, with
an inductance of 1 mH. The internal primary coil had only three turns and was arranged to slide into the antenna coil, being moved by ropes leading to a position near the modulator case (ref. 2).

Gaseous power tubes were eliminated during rack testing, but seemed to remain a recurrent source of difficulty throughout the tests. When a second rack was added to the first the power doubled, but when a third rack was connected the power did not increase proportionately. A fourth rack seemed to add nothing and the fifth actually dragged the power down. The problem was the progressive phase shift caused by each rack being connected to its neighbor. The solution lay in taking separate leads to and from the distribution panel to each rack.

The receiving equipment was designed and made by Hartley and R.H. Wilson, assisted by B.W. Kendall. Craft and Colpitts reported the following (1):

"The method of reception was varied from time to time as it was still in process of development. In some cases an amplifier for the high-frequency currents was introduced between the detector and the tuned circuit which was coupled to the antenna. In some cases a low-frequency amplifier was inserted between the detector and the receivers. In some of the later experiments a feed back circuit was used for the detector so that the detector tube itself acted as an oscillation generator as well as a detector. In that case the frequency of the oscillations was adjusted to be the same as those of the oscillation generator at the transmitting station (sic)." (1)

Presumably they were using regeneration in the latter experiments.

**First Tests at Arlington**

With only about 200 tubes in operation testing began. R.H. Wilson at the U.S. Navy Station at Darien, Panama, was able to hear Arlington over a distance of about 2,100 miles. W. Wilson in San Diego, and
Hartley at Mare Island, California, set up and operated receivers at these two naval stations, equipped with a wire-telegraph circuit to report back to Arlington. On Sunday, 4 July, 1915, Carty and Jewett, confident of immediate success, wished to make the first transcontinental speaking tests themselves, even though atmospheric conditions were at their worst and they were running on less than half power. Carty went through an elaborate series of speech tests moving progressively further away from the microphone without waiting to hear whether Hartley was getting anything at all. Arnold, well aware that only the maximum degree of modulation would stand a chance of getting through, followed Carty’s antics by increasing the audio gain every time the microphone output decreased. In spite of Arnold’s well-intended intervention their signals were not very intelligible, and Carty was not pleased with Arnold for compromising the integrity of his tests. It was not a very good independence day for either of them.

Tubes continued to blow and each time this happened they tripped the Navy circuit breaker. Worse still, some of the trips were so serious that they produced pitting on the generator commutator. The Navy maintenance men were incensed and they were obliged to add resistance to the feeder cable to limit the short-circuit currents.

The noise made when a tube imploded was considerably enhanced by the glass shards cascading down over tubes beneath it and coming to rest only after hitting the fan blades at the bottom of the rack.

Replacement tubes continued to arrive in a steady stream from New York, but the failure rate made sure that the total in service did not increase rapidly. In the meantime they busied themselves with checks and improvements. The antenna resistance was found to be 2 ohms, and calculations revealed that sidebands beyond one kHz were being seriously attenuated. By increasing the antenna coupling the speech quality improved, at the expense of reduced antenna current.

Convinced that the tests would be successful, orders had been given to manufacture an additional set of racks holding 300 power tubes which could be used at the distant end to permit both-way operation. The layout and construction of these new racks differed from those already delivered to Arlington. All six were designed to stand together as a suite with interconnections and cooling ducts installed in the workshop.

As it became clear that success would depend on having much more power, this suite of racks was diverted to Arlington and squeezed into the little remaining space. When these were connected to the two existing bays the usual problem of “singing” returned, and it took a week to find connections which would defeat the problem. Power tubes continued to arrive in a steady stream and the number in operation rose to about 550. With this many in service there were several tubes failures each day,
and the rate of arrival of new tubes only just kept up with the losses -
full capacity was therefore never reached.

**Successful Demonstrations**

Radio-telephone transmission from Arlington to the large U.S. Navy
antenna at Mare Island, 2,500 miles distant, was formally demonstrated on
29 September with Arnold and Hartley operating the equipment. Carty
arranged for Cmdr. G.C. Sweet and Lt. Kenshit of the Navy, and A.H.
Babcock, consulting engineer of the Southern Pacific Railroad, to witness
the tests. A telephone line between Vail's New York apartment and Arlington
made it possible for him to speak to Carty via the radio link, whilst the return
signal was carried by long-distance telephone. At New York the line from
Mare Island was extended to Vail's apartment, and also to Arlington, so that
a party of guests gathered there could follow both sides of the conversation.
Vail and a group of senior company officials spoke from his apartment while
Cmdr. Bryant observed the tests at Arlington. The demonstration was
successful, but as Espenschied pointed out, they had been careful to choose
the best time of day.

**Figure 20.** H. W. Everitt playing the cornet over the Arlington transmitter.
A special high-quality microphone was used during the tests (Figs. 19 and 20). Musical frequencies were supplied by a phonograph using an electrical pickup, and by H.W. Everitt, who played his cornet over the air.

The following evening a test to Pearl Harbor Naval Station, near Honolulu, scheduled so that conditions would be at their best, was successfully completed. This was actually the greatest distance (4,900 miles) to be spanned during the whole series of tests and Espenschied, who manned the equipment, was able to cable details not only of the words spoken but also named the speakers (John Mills and Heising). This was achieved in spite of the fact that they had to use a small temporary antenna strung between a smoke stack and a water tank because, for some reason, the regular antenna at the station was not suitable.

Heising recalls the reaction of the Commanding Officer at Pearl Harbor when he eventually came to listen to a telephony transmission from Arlington:

"The Commanding Officer had been as skeptical as Capt. Bullard of our securing any results in the proposed tests, and so had given no attention to Espenschied's work during the months previous. He was still skeptical when he listened to the demonstration. The speech was sufficiently clear to enable much to be understood and speakers' voices recognized. Espenschied reported the incident as follows: The admiral was given a pair of phones and told that the speech to be heard therein was coming from the transmitter at Arlington. He seemed to pay little attention but put on the phones. The speech must have surprised him. He stopped and asked Espenschied, 'Where did you say the signals were coming from?' 'From Arlington,' Espenschied replied. He listened a few moments again, and then turned to his aide. 'Where are the signals coming from?' 'From Arlington,' replied the aide. He listened a few seconds more, then laid down the phones, turned around and walked out without a word. Espenschied felt he didn't believe a word that was told him. Later Espenschied found out from the aide that the Admiral quizzed him further as to how he knew the signals were from Arlington. Subsequently the cabled reports from the U.S. were published in the newspapers, convincing the Admiral that he was not the mere victim of a hoax, so he added his confirmation to those previously made." (2)

**The Receiving Station at the Eiffel Tower (Paris)**

Attention then turned to reaching Paris from Arlington (3,800 miles). France was in the thick of World War I, and the Eiffel tower (1,000 ft high) antenna was in constant use for monitoring enemy transmissions. The war was still in a critical phase - only twelve months previously.
"...the Germans had been near the outskirts of Paris and were stopped only by rushing reinforcements in a fleet of Paris taxicabs." (4)

According to H.E. Shreeve,

"At night, for instance, from the top of the Eiffel Tower, the flash of the guns on the firing line is plainly visible." (5)

The French Government was approached and, even though the tests would be of no help to their war effort, they agreed to provide accommodation for the equipment and to make the antenna available for short periods. Lt. Cmdr. Ferrié, Capt. Brenot, Capt. Pincimin, Lt. Valbreuze and several officers of the French Radio Telegraph Service showed a great deal of interest in the project and made the necessary arrangements. H.E. Shreeve and A.M. Curtis had traveled to Paris to install and operate the receiving equipment. Towards the end of September, 1915 the antenna was made available for tests for about ten minutes at some time between 5:00 a.m. and 5:30 a.m.

Initially a transmission frequency of about 50 kHz was used, but it was almost impossible to hear a weak signal in the face of several powerful European telegraphy stations transmitting on nearby frequencies. The cable link between Europe and the U.S. was monopolized by military needs, but eventually they were able to rearrange the program so that alternative frequencies of 40 kHz and 60 kHz could be tried.

The change of frequency did the trick, and between 12 and 20 October snatches of speech came through. But it was not until 21 October that Shreeve and Curtis and a few French observers heard B.B. Webb in Arlington say, "Hello, Shreeve" several times and finally, "And now, Shreeve, good night." On 23 October a formal demonstration was arranged for senior officials, including Cmdr. Sayles (Naval Attaché to the American Embassy) and several French Army representatives.

The Atlantic had been crossed and the point made that it was possible to speak to Europe, so Shreeve and Curtis packed their bags and returned home. Reising's reports as follows:

"The news of the radio tests created quite a stir in the country. Most every radio amateur in the country must have tuned in to hear us. I believe many were disappointed as we published no schedule of time or wavelength although we continued our tests to reach Paris" (2).
Lee deForest Takes an Interest in the Tests

Lee de Forest also read the press reports and to quote Heising,

"Dr. de Forest was probably the individual who was most deeply stirred by the news. He rushed into print quickly to secure all the publicity he could get out of it and talked as though he knew all important details of the apparatus. However, he must have felt that he needed more information because he suddenly showed up at Arlington to try and pump Capt. Bullard. Dr. de Forest arrived there just as we were all sitting down to lunch. All summer we ate lunch at midday at the officer's mess in the Naval Building. Capt. Bullard always sat at the head of the table. When de Forest arrived Bullard invited him to have lunch with us, and he accepted. All of us were introduced, but as far as his interests were concerned, we might as well have been posts. Bullard had only mentioned our names, and he supposed we were all Naval people. De Forest immediately began to try and pump Bullard as to our apparatus. He asked question after question which Bullard either parried or said he didn't know. Finally Bullard told him that if he wanted information about the apparatus he should ask the telephone company representatives, and called his attention to Webb, Everitt and myself at the table. De Forest turned his head quickly and looked at us for some seconds with astonishment, just as though we had mysteriously appeared at the table from nowhere. He said nothing, however, but dropped all talk of the subject with Bullard.

"De Forest apparently noticed that our tests were continuing and he conceived the brilliant idea of going to Europe and listening to our signals over there, and then get all the publicity he could out of it. Our people got wind of it when he sailed, and got further word of his sudden arrival in Paris. Before he could make arrangements to listen to us, however, we succeeded in completing our tests and stopped our transmissions. A.M. Curtis has an interesting story of de Forest's efforts to get permission to listen in Paris and of the suspicion of the French that he was some spy. Before throwing him in jail, however, they asked Shreeve if our people knew him. Upon Shreeve explaining de Forest's interest in our tests they were satisfied as to the cause of his suspicious behavior, and did not molest him. De Forest to this day doesn't know how near he came to going into the calaboose."

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The Problem of Changing Transmission Frequency

Before success in crossing the Atlantic could be achieved several changes of transmission frequency were required. Heising makes the following observations about the process:

"The shifting of wavelength was none too easy to handle with the type of circuit we had. First the oscillator frequency was changed to a calibrated point. Then the output circuit from the modulator was retuned. Then the antenna coil was connected to a different tap. Then the resistance elements in the output circuit from the amplifier were readjusted so the power tubes didn't sing. Then the oscillator was readjusted slightly to the resonant antenna frequency; then all intermediate tuned circuits were readjusted as well as antenna coupling, and finally the coupling for adjusting the voltage on the modulator from the oscillator was changed. Then we were ready to apply increasing plate voltages up to full voltage with maximum power adjustment on the modulator, which if correct allowed us to switch to talking adjustment and begin to send signals." This process took at least twenty minutes.
Heising states that each tube delivered only four watts (unmodulated) which rose to a peak power of fifteen watts when fully modulated. With 550 tubes in operation, the Arlington transmitter would therefore have delivered about 2.2 kW unmodulated, and about three kW fully modulated.

After the Paris tests several demonstrations were arranged, and Carty gave a dinner in New York to celebrate his election to the Lotus Club, at which he provided each guest with a pair of headphones so that they could listen to a radio-telephone message sent from Arlington. Those engineers not required to operate the equipment were invited to the dinner and were as much impressed with their first acquaintance with Champagne as the official guests were with the demonstration.

**First Fruits of the Tests**

Several demonstrations were given to Army and Navy top brass. Secretary of the Navy Daniels asked for a two-way telephony demonstration with a ship at sea. A low-powered transmitter and a receiver were constructed and installed on the *U.S.S. New Hampshire*, which in conjunction with Arlington and a land-based receiver at Norfolk, VA, provided a full telephone link between Secretary Daniels and Capt. Chandler while the *New Hampshire* was in Hampton Roads. Telephone lines were then used to extend the link to the Great Lakes Naval Station and then to Mare Island, so that the Commandant, Capt. F.M. Bennett, could converse directly with Capt. Chandler, with the ship up to fifty miles from Norfolk. The equipment on the *New Hampshire* was located on the lower deck, with the telephone transmitter and receiver installed on the bridge.
Commander Hooper of the Bureau of Steam Engineering then asked Western Electric to provide two experimental sets for installation on battleships, to give his staff an opportunity to evaluate radio telephony from an operating point of view. The circuit diagram for these two sets is shown in Fig. 22. The wavelength could be set between 600 & 1200 meters (250-500 kHz). The low-power transmitter produced about one ampere in the antenna. This was sufficient to cover the prescribed range of thirty miles, and in practice they were heard up to 175 miles away. Sets were installed on the battleships Arkansas and Florida at Guatanamo, Cuba, early in February, 1916 (Fig. 23). This is the only illustration which shows a short version (presumably type S) of the type-W tube.

The main problem encountered was interference from existing telegraphy equipment, and it was decided to move to much shorter wavelengths so that they could completely separate wireless telephony from telegraphy. A few field experiments were made, with short-wave antennas on two ships, in July 1916, and a new design study was started in October.

Heising devised a system of multiplexing in which the transmitted carrier could be modulated with a speech sub-carrier of either 25, 35 or 45 kHz. The intention was to allow up to three ships in the same neighborhood to send on the same carrier frequency, provided each used a different sub-carrier. In addition, a choice of three carrier frequencies was available with wavelengths of 150, 189 and 238 meters (about 2, 1.59 & 1.26 Mhz). It was intended that equipment could be operated simultaneously by up to nine ships in the same area without mutual interference. Simplified diagrams of the transmitter and receiver are reproduced in Figs. 24 and 25. Sets were installed on the U.S.S. Pennsylvania, Wyoming and Seattle.
in January, 1917. Soon afterwards, however, diplomatic relations with Germany were severed (3 February, 1917) and the Navy was no longer available for tests. It appears that this was the first practical application of the "carrier" principle. The author has no further information about these sets (illustrated in Fig. 26) and would be interested to know whether they were successful and whether any similar system was ever used in the field.

President Wilson ordered the arming of American merchant ships so that they could defend themselves against U-boat attacks, and on 6 April, 1917 the U.S. declared war on Germany. In March the Navy requested fifteen experimental sets for use on submarine chasers. These were essentially C.W. telegraphy sets, but they also carried a telephony attachment. Four type-W tubes were used in the output stage, delivering 1.5 amperes to the small antenna on the 110-foot vessels. These sets were replaced soon afterwards by equipment which will be described later.
American aviation was still in its infancy when the U.S. entered World War I. The army had a small airforce unit, under the control of the Signal Corps, which consisted of 65 officers and 1,087 men but not a single combat aircraft. The Naval air arm had 38 aviators, 160 enlisted men and possibly a dozen hydro-airplanes based at Pensacola, but none of these carried armaments. Wireless telegraphy using spark equipment had been tested between air and ground (an example of a British test is shown in Fig. 27) but was hardly suitable for use in combat.

In these circumstances someone at A.T. &T. must have had remarkable foresight to start experimenting with radio telephony for use in aircraft. H.W. Nichols was appointed to direct the work and A.T. &T. developed a short-range experimental set. This was successfully demonstrated but was not acceptable because of its weight (Fig. 28).

A meeting was held in Major General Squier's office (Chief Signal Officer of the Army) in Washington on 22 May, 1917, attended by Col. Rees of the Royal Flying Corps of Great Britain and Capt. C.C. Culver of the Signal Corps with Major F.B. Jewett and Major E.B. Craft of the Western Electric Company. As a result of this meeting the company was ordered to proceed with the development of a radio-communication system to

Figure 26. A multiplex transceiver for the Navy.

Aircraft Telephony

Figure 27. A British "Flanders" monoplane equipped with wireless telegraphy before 1914. (16)
provide reliable short-range communication between aircraft.

Within six weeks a telephony link with flying aircraft was demonstrated, followed soon after by successful communication between planes in the air as well as with the ground. But serious problems arising from the difficult environment encountered in the flying machine had still to be solved. The noise from the engine combined with the rush of air in the open cockpit did not make it easy to hear voice signals, nor was it a favorable background for reproducing speech.

The padded leather flying helmet incorporating the headphones started life here and solved the audibility problem (Fig. 29). The speaking difficulty was tackled thus: "A brilliant line of experimentation, largely at the hands of J.P. Minton of the Transmission Laboratory, resulted in a form of a telephone transmitter or microphone, which possessed the remarkable quality of being insensitive to engine and wind noises, and at the same time very responsive to the tones of the voice." (7)

The team had to ensure that the equipment could withstand severe jolts and vibrations without adding excessively to the weight, as those early aircraft had a limited carrying capacity. Batteries would have been the most convenient form of power supply but had to be rejected because of their weight. They were not permitted to couple...
Figure 30. Wind-driven generator to power radio equipment, fitted to a Curtiss J.N. "Jenny" trainer.

generators directly to the engine, and finally solved the power-supply problem by using a 100-watt outboard wind-driven generator (Fig. 30). The airspeed could vary from forty to 160 miles per hour and the corresponding generator speed ranged between 4,000 and 14,000 RPM. H.M. Stoller devised a regulator circuit exploiting the rapid change of diode anode current with increasing filament voltage (Figs. 31 and 32). The rotor had separate windings and commutators for the high-tension and the low-tension supplies. Two field windings were provided; the main coil was fed via the regulator-diode filament from the low-voltage supply, and the current for the second differential coil depended on the anode current passing through the diode. As the speed of the generator rose the diode-filament current increased until the filament reached its normal operating temperature. The diode-anode current then rose rapidly and produced an opposing flux in the differential field which minimized any further changes in output. This must surely be the first electronic control circuit!

Figure 31. Voltage regulation of wind-driven generator.
The antenna consisted of a 200-foot trailing wire, terminated in a lead weight which could be reeled in or out as required. This appendage was acceptable when flying alone but was embarrassing when flying in the presence of other aircraft. Ignition interference had to be eliminated by using screened high-tension cables.

Finally on 2 December, 1917 the equipment was demonstrated to the Aircraft Production Board and the joint Army and Navy Technical Boards at Moraine Flying Field in Dayton, Ohio. This crucial test was described as follows:

"The planes left the ground and after what seemed to be an interminable length of time, we got the first sounds in the receiver, which indicated that they were ready to perform. The spectators were only mildly interested, and some seemed to be a bit bored. Suddenly out of the horn of the loud speaker come the words, 'Hello, ground station. This is plane No. 1 speaking. Do you get me all right?' The bored expression immediately faded, and looks of amazement come over their faces. Soon we got the same signal from No. 2, and the show was on. Under command from the ground the planes were maneuvered all over that part of the country. They were sent on scouting expeditions and reported what they saw as they traveled through the air. Continuous conversation was carried on, even when the planes were out of sight, and finally upon command they came flying back out of space and landed as directed." (7)

"From that moment the radiotelephone was sold. It was not a question after that as to whether it would work or was any good, but how soon could we start manufacture and in what quantity."

Before the first SCR-68 transceivers could be delivered early in 1918, an exhaustive process of evolution and testing had to be endured.
Figure 33. Circuit diagram of the complete SCR-68 transceiver.

Figure 34. Complete set of equipment (SCR-68) for a two-place airplane.
of 690 test flights were required. A.A. Oswald alone made 302 flights, clocking up 484 flying hours, and lived to tell the tale. As E.B. Craft put it,

"It is a truly remarkable and happy fact that during all this flying, not one serious accident was recorded. It is no use talking about the narrow escapes, for in this game also, a miss is as good as a mile" (7).

Major General Squires' gives statistics on training during World War I (Figs. 35 & 36) and comments,

"It will be seen that our training casualties have been astonishingly few. Statistics show that the U.S. has a lower percentage of fatalities than any of the other allied countries. The monthly average has been only one fatality for each 3,200 hours flown" (8).

The equipment delivered five watts in the frequency range 600-1500 kHz (see Fig. 33 for circuit diagram). By this time Heising had perfected the class-C amplifier and his constant-current modulator which together produced a more effective and efficient transmitter. VT-2 tubes were used for both the modulator and the power oscillator. The receiver had a grid-leak detector followed by two stages of audio amplification using
VT-1 tubes. Two sets of microphones and headphones were provided for intercommunication between the fore and aft cockpits in addition to serving the radio function. The intercommunication capability was an important advantage, as previously the only means of conveying information between the pilot and his passenger was by hand signals. All together the equipment weighed 58 lb.

The original requirement was for reliable communication for distances up to 2,000 yards, but in practice it was possible to communicate between planes up to 23 miles apart and 45 miles from the ground station.

Fig. 37 shows a variation of the transceiver (SCR-67) primarily intended for use on the ground by training instructors wishing to send comments and instructions to pupils in the air. By the end of the war many thousands of these sets had been manufactured and installed in aircraft in the U.S. and in Europe.

The whole emphasis in designing this equipment had been on the need for quick results, and little time was allowed to determine optimum choices. This was especially true of the low operating frequency requiring a long trailing antenna which could be hazardous in combat or close flying formations. Before the end of the war further work was done between 2-4 MHz with shorter antennae. Fig. 38 shows the resulting equipment which was split up into smaller modules to make it easier to accommodate in confined spaces. Antenna wires extending from the wing tips to the tail were tried, but although this was better aeronautically it did not have good radiation characteristics. The best solution used two short antennae trailing from the wing tips and joined across the wing with the airframe as a counterpoise. Fig. 39 compares the radiation patterns for the original single long wire with that of the double antenna.
Submarine Chaser Radio

The aircraft radio was so successful that the Navy decided to use similar equipment on their small 110-foot vessels for chasing enemy submarines. The CW-936 transceiver provided two-way communication between commanding officers aboard vessels involved in a chase. A hand-held microphone and either headphones or a loudspeaker was provided in the pilot house. Any one of five wavelengths (250-600 meters) were available to provide selective calling. Several thousand of these sets were installed in chasers stationed mainly in Europe — Figs. 40 and 41 shows the transmitting and receiving units.

Postwar Developments

The pace of radio-telephony development slowed down abruptly after 1918. Some attempts were made to provide a telephone service to ships at sea and a few point-to-point radiotelephone links were established,
but these were discouraged by the postwar slump. Telephony required more bandwidth than telegraphy and with the demand for air space growing rapidly the need for lone frequency allocations became increasingly urgent. Until international agreements were reached no one wanted to spend money on developing new systems.

Before a regular transatlantic telephony service could be implemented much more spade work had to be completed. Telegraphy over the same distance had been operating for some time using wavelengths below 30 kHz; these had dependable characteristics but were not suitable for telephony. When conditions deteriorated a telegraph operator could ask for a spoiled message to be repeated, and if necessary traffic could be held up until conditions improved. Telephony users would not tolerate such compromises and a much more consistent path was required.

The obvious way to improve the signal-to-noise ratio was to increase the transmitted power, but this had to be achieved with far fewer tubes than were required at Arlington. W. Housekeeper of Western Electric
developed a new glass-to-metal seal in 1919 which allowed the metal anode to become part of the sealed tube envelope. Now, instead of being enclosed within a glass tube, the anode could be exposed directly to the cooling medium, and transmitting tubes capable of dissipating ten kW and more could be made (Fig. 42).

In 1915 J.R. Carson at Western Electric developed single-sideband modulation for use in wire transmission, and it was quickly realized that this could convey intelligence much more efficiently than simple amplitude modulation.

Studies revealed that most atmospheric noise originated in the tropics. By locating a receiver as far north as possible and by using a directional antenna the signal-to-noise ratio could be improved significantly.

In 1923 all of these improvements were brought together for a test on 60 kHz, using the large RCA antenna at Rocky Point, Long Island, to transmit to a big loop antenna in England. This time speech of consistent commercial quality came through, and this led the way to a two-way telephone link which was put into regular service in January, 1927.
Figure 43. The team that did most of the field work on the airplane radio telephone. Left to right: J.P. Minton, R. Guenther, E.B. Craft, L.M. Clement, R.A. Heising and A.A. Oswald.

Figure 44. Part of the research and design team on the radio-telephony projects. Standing (left to right): W.A. Boyd, E. Wilson, W.E. Booth, H.M. Stoller, C.S. Winston, G.H. Stephenson; Seated: H.J. van der Bijl, J.J. Lyng, H.W. Nichols, W.T. Booth.
The promise of the Arlington tests had at last been realized and the “Grand System” of Alexander Graham Bell, in which any person would be able to talk to anyone anywhere in the world, was another step closer.

Craft and Colpitts, in their paper published in February, 1919, took a glimpse into the immediate future and predicted that radio telephony would prosper in three main areas:

“.... These stations (radio) will be of two kinds: Moving, such as ships, airplanes, trains, trucks; and fixed but inaccessible, such as on islands, in deserts and in very sparsely settled regions.

“A third class of service is that which is concerned, not with single individuals, but with groups; such as the broadcasting of news, time and weather signals, and warnings. In some cases one objection to radio telephony would be an advantage in this class of service.”

Western Electric moved into this third class of service shortly afterwards and produced hundreds of radio broadcasting transmitters which found their way all over the world, including Johannesburg, South Africa.

It is rare to find a chain of events that remained so consistently favorable. Carty’s determination to proceed with the Arlington tests, which could hardly have been expected to return immediate benefits, led to the participation of the Navy through the use of their Arlington facilities. This in turn
meant that the tests were familiar to the very people who would require telephony equipment when war broke out. By looking ahead and seeing the value of radio telephony in aircraft, Western Electric jumped several steps ahead of their competitors and were ready to show that they could provide equipment when it was most wanted. Under Vail the company had introduced some of the finest research facilities in the world, and these had ensured that their technology advanced sufficiently to keep them foremost in the business. The cost had been considerable, and the company’s earnings had suffered, but the dividend came in the form of dependable growth.

Some of the conclusions to Heising’s report on the tests were as follows:

"The consensus of opinion of those of us who worked at Arlington was that there probably would never be another transmitter like it .... Aside from technical matters, the experience at Arlington stands out so that it will always be remembered. It is one of the things I can always look back to with pleasure. It is one of the landmarks in my life, or expressed another way, is an event to reckon time from, and the latter I do very often."

Figure 46. Copy of letter sent to Dr. H. J. van der Bijl in 1940 at the dinner commemorating the 25th anniversary of the Arlington radio-telephony tests.
On 21 October, 1940 fifteen of the original team of engineers involved in the Arlington tests assembled at the Bell Telephone Laboratories, 25 years after the first successful radio-telephone reception in Paris. It would have been appropriate to have reenacted the achievement by speaking over the telephone to someone in Paris, but by this time World War II had intervened, and instead Dr. F.B. Jewett spoke to A.A. Scott, the president of the Mutual Telephone Company in Honolulu. To quote from the New York Times report of the occasion:

"As they took turns in participating in the call, more than one was heard to remark that the connection was 'as good as a local call' and that it was a marked contrast to the weak tones received, in 1915, from the Arlington radio station of the United States Navy amid crashing static."

H.E. Shreeve commented that after repeated failures he and his partner were disconcertingly dubbed "Yankee bluffers," and it was with "relief in justification" that they finally picked up the Arlington call clearly. Afterwards they attended a dinner at the University Club, and to quote again from the newspaper,

"A participant in the 1915 tests unable to attend was Dr. H.J. van der Bijl, now Director General of War Supplies for the Union of South Africa." Fig. 46 shows the note sent to him signed by those present.
Acknowledgements:

The author wishes to acknowledge the help and assistance which he received from the American Telephone & Telegraph Company Corporate Archives when they were still at 195 Broadway, New York and from Barbara Sweeney at Warren, NJ. He would also like to thank Frank Tormey, Managing Director-Africa (A.T. & T. Communications Services (Pty) Ltd) for his personal help and interest during the preparation of this material.

He would like to pay special tribute to his wife, Irene, for her encouragement and help throughout the long period of preparation. It was she who taught him most of what he knows about writing through her patient editing of his drafts.

Illustrations

The following illustrations are the property of the A.T. & T. Archives and are reprinted with the permission of A.T. & T.: Figs. 2, 4, 6-21, 28-34, 38, 39, 42-45. Unfortunately most of the pictures relating to R.A. Heising's notes (ref. 2) had to be reproduced from Xerox copies of the originals (made in 1984) resulting in a loss in quality.

APPENDIX -

Further information on some of the key figures:

Theodore N. Vail

Born 16 July, 1845, Minerva, Ohio    Died 16 April, 1920, Baltimore
His successful career in the Railway Mail Service culminated in his appointment as general superintendent in 1876. The Bell Telephone Co. persuaded him to take on the job of general manager in 1878. He was made president of A.T. & T. from 1885 until 1887 and again from 1907 until he retired in 1919. Although he had no technical training he had a nose for the right projects to back, and had a significant influence on the growth of the company.

John J. Carty

Born 14 April, 1861, Cambridge, Mass    Died 27 December, 1932
Started in the New England Telephone and Telegraph Company as a boy telephone operator and rose through the technical ranks. He became
Frank B. Jewett

Born 5 September, 1879, Pasadena, Ca. Died 18 November, 1949

Graduate of Throop Polytechnic in 1898 (now California Institute of Technology). Awarded Ph.D. at Univ. of Chicago in 1902. Taught physics at M.I.T. and then joined A.T. &T. as transmission engineer in 1904. Became vice-president of A.T. & T. in charge of research in 1925, and was president of the Bell Telephone Laboratories from 1925-1940, and then chairman of the board of directors.

Harold DeForest Arnold, Ph.D

Born 3 Sept., 1883 in Woodstock, Conn. Died 10 July, 1933 Summit, NJ

Trained at Wesleyan University, Conn. Post graduate studies at Chicago University under Prof. R.A. Millikan. He joined Western Electric Research Branch in January, 1911. Produced a mercury-vapor discharge-tube amplifier and then headed the team which developed the Audion into a practical amplifier for telephone and radio work. He stimulated fundamental research into speech and hearing which was eventually used to define realistic limits to distortion in sound-reproduction systems. G.W. Elmen and Arnold worked on Permalloy, a magnetic material with exceptionally high permeability which was used in audio transformers and also wrapped in tape form around submarine telegraph cables to provide continuous loading. In 1925 he became director of Research at the start of the of Bell Telephone Laboratories.

(Question: Was Arnold related to Lee de Forest?)

Edwin H. Colpitts (15)

Born 1872 in New Brunswick, Canada. Died 1949

Graduated from Allison University in 1893. Received his B.A. and M.A. from Harvard in 1896 and 1898. Joined Bell Telephone Co. in Boston in 1899 to work with G.A. Campbell on telephone-line loading coils. In 1907 he became a research engineer with the Western Electric Co. in
N.Y. working on cable and radio-telephone systems. In 1911 he was appointed head of the Research Branch of Western Electric where he had a direct impact on the development of radio telephony. He became Vice President in the Dept. of Development and Research of A.T. & T. in 1924 and was Vice President of the Bell Telephone Labs. from 1934 until he retired in 1937.

**Ralph V. Hartley**

Graduated from the University of Utah and became a Rhodes scholar. In the mid '20s, following the work of Nyquist at A.T. & T., he published an important paper on information theory which was only overshadowed by Shannon in 1948.

**Raymond A Heising**

Born 10 August, 1888, Albert Lea, Minn.

Graduated from the University of N. Dakota in 1912 and gained an M.S. degree from the University of Wisconsin in 1914, and then joined the Research Dept. of Western Electric. He was eventually granted 117 patents covering radio circuits, modulation, multiplexing, etc. In addition to the work outlined in the body of this article his early work led to multi-channel carrier-telephone systems. In the ‘30s he became interested in U.H.F. and piezoelectric phenomena. He was elected president of the IRE in 1939.

**Hendrik J. van der Bijl**

(pronounced fun der bale)

Born 23 November in Pretoria, S. Africa   Died 2 December, 1948

He was the 3rd student to receive the degree of BA in Physics from Victoria College (now Stellenbosch University) in 1908. Did his postgraduate studies in Germany at Halle, Leipzig and Dresden. He came to the attention of Prof. A. Millikan of the University of Chicago at a conference in Germany. On Millikan’s recommendation, F.B. Jewett offered him a position under Arnold to work on the Audion which he took up in 1913. Most of the mathematical relationships between tube parameters were developed by him and culminated in his book on the vacuum tube. 1920 General Smuts persuaded him to return to S. Africa as a Scientific Advisor to the government. He was largely responsible for starting the Electricity Supply Commission which generated and distributed electricity nationwide, and subsequently the Iron and Steel Corporation which was the first significant industry, apart from gold mining, in the country.
At the start of World War II he was made Director General of War Supplies. Van der Bijl contributed more than anyone else to the development of industry in S. Africa.

Lloyd Espenschied

Born 27 April, 1889, St. Louis, MO

Built and operated one of the first amateur wireless stations in 1904 and worked as a wireless telegrapher for the United Wireless Telegraph Co. He graduated from the Pratt Institute in 1909. Joined A.T. & T. in 1910 to work on loading of lines and high-frequency transmission on wires and radio. He became director of high-frequency transmission at the Bell Telephone Laboratories in 1934 and was involved in the development of coaxial-cable systems. He invented a sharp cutoff quartz crystal band-filter for carrier systems, and among his more than 100 patents are an aircraft altimeter and other radio-wave reflection devices. He was awarded the Medal of Honor of the IRE in 1940. After his retirement in 1954 he published a number of papers on the history of electrical technology.

References


3. Notes on the Radio Telephone Experiments of 1915 (by Lloyd Espenschied?).


Dirk was born in 1930 and has spent most of his life in Johannesburg, South Africa. The radio bug bit Dirk in junior school in about 1941. His guide was a chum (Harry Moir, now living in Orlando, FL) whose father had been making radios since the '20s. He gained a BSc in Electrical Engineering (light current) from the University of the Witwatersrand in 1951. He then moved to England for industrial experience at the Automatic Telephone and Electric Co., Liverpool (a company spawned by the Automatic Electric Co., USA.) As a bonus he found there a wife who, after they had returned to South Africa, brought four wonderful children into their lives.

A short period with the South African Post Office telephone department convinced Dirk that he did not wish to work for the civil service and he moved on to do development work for the gold mining industry. He produced special two-way underground radio equipment radiating through rock at 350 kHz for use in the mines.

Subsequently he became a partner in a small company manufacturing electronic railway signaling equipment. Dirk retired in 1974, leaving him time to indulge in his special interests such as the history of Electrical Engineering, particularly in South Africa.

In 1986 he visited the USA as a consultant to the South African Broadcasting Corporation Museum and attended the AWA Annual Conference at Canandaigua. While in New York he requested information from the AT & T Archives section relating to the work of the South African, Dr. Hendrik van der Bijl, author of the Vacuum Tube and its Applications, published in 1920. In response he was given a pile of photocopies, and included with these was the story of the Western Electric radio developments during 1914/15, which forms the basis of this article.

Apart from historical research Dirk heads a team attempting to start a Science Centre in Johannesburg.
Figure 1. The Western Electric motor and generator mounted in the A-3 Privacy Device, made by the Bell Telephone Laboratories specifically to give security and short-term privacy to radio-telephone communication circuits. This was the heart of the equipment that was used on each end of the original transpacific radio-telephone circuits...this one located in Honolulu and a similar one in San Francisco. The units cost $36,000 each.
TRANS-PACIFIC RADIO-TELEPHONE CIRCUITS
AND THE A-3 PRIVACY DEVICE

Roy S. Blackshear, KH6BAI
Keaau, HI

INTRODUCTION

On November 2, 1931 the Mutual Telephone Co. (now the Hawaiian Telephone Co.) attained a long-sought-after goal when inter-island radio-telephone service became a reality and united the six major islands in what was then the Territory of Hawaii. RCA was the builder of this inter-island system. (Note: RCA succeeded American Marconi in 1919) Upon the establishment of this service David Sarnoff, President of RCA sent Mutual’s president, John A. Balch, the following radiogram:

“Everyone here highly elated to learn that the opening of your inter island ultra-high-frequency radio-telephone system was so successful, especially the long circuit to Hawaii (Honolulu to Hawaii Island) stop. We congratulate you and your competent staff for successfully putting over this difficult pioneering enterprise.”(1)

TRANS-PACIFIC RADIO TELEPHONE SERVICE

Earlier, while the inter-island experiments were being carried out, the Mutual Telephone Company’s President Balch opened negotiations with the American Telephone and Telegraph Company in New York to operate a commercial radiotelephone service between the islands and the West Coast, supplying Mutual customers with mainland telephone connections. The agreement included the erection of radio-telephone stations on the (west) coast. [2]

A second accord was negotiated with RCA, who already had a wireless telegraph station in the islands, in which RCA agreed to supplement it by establishing and operating the necessary receiving and transmitting equipment at Kahuiku and Koko Head, both sites located on Oahu Island. [3] RCA was responsible for constructing both sites— the transmitter at the Kahuiku site on the northern tip of Oahu Island, and the receiver at Koko Head on the southeastern end of Oahu Island, within sight of Diamond Head. [4]
"The first conversation between Hawaii and the mainland was carried out on November 20, 1931 over the new circuits. The circuit was opened by Mr. Roberts who established connection from the technical operator’s position in the control room on the second floor with San Francisco and then asked for New York." (second floor refers to Mutual Telephone’s headquarters in downtown Honolulu.) “Connection was established with J.J. Pilliod, Chief Engineer of the Long Lines Dept. (of AT&T) who talked with (Mutual’s) President Balch. Using a handset in the control room, Balch spoke for over an hour.”[5] Note: The first radio communication between Hawaii and the mainland occurred about September, 1908.[6]

On December 23, 1931 overseas transpacific radio-telephone service between Hawaii and the mainland was inaugurated. So important was this historic event that arrangements were made to have the calls made by dignitaries from the Throne Room of historic Iolani Palace in downtown Honolulu. [7]

Security and Privacy

Initially there was one transpacific radio-telephone circuit using five different frequencies. However, because of this design, the circuits lacked complete security and privacy.

The Bell Telephone Laboratories were aware of the problem and had been working on short-term privacy systems since about 1920, when the use of radio telephone communication was under early consideration. The A-3 System used on later overseas systems, while moderately easy to break, did provide enough security for most commercial purposes, particularly when combined with private codes which were frequently used in critical business conversations. [8]

“Many privacy systems had been invented before the war. A patent search was made in 1941 by E. W. Adams and it disclosed a large number of possible techniques but test and analysis showed that most of them had no practical value. Only three of the many ways to manipulate speech were explored extensively. These were rearrangement of frequencies, rearrangement of time order, and noise masking.” [9]

When I worked at Hawaiian Telephone Co. I had the pleasure of knowing a fellow management employee, Maurice V. King, Jr., better known to all as Maury. Whenever there was a difficult technical problem it was referred to Maury, who always came up with the solution. Maury and I had many talks, and he was interested in the fact that I was a collector of antique artifacts that should be preserved for future generations.
He and his wife visited my home several times on Hawaii Island to see my collection of antique telephones, radios, phonographs and cameras, and often commented that at last someone in the Hawaiian Telephone Company was collecting and saving items destined for the junkyard.

In 1932 the Bell Telephone Laboratories manufactured and sent to the Mutual Telephone Company in Honolulu what became known, to the employees familiar with it, as the “A-3 Privacy Device.” This unit was for the Hawaii end of the radio-telephone circuits and another similar device was sent to San Francisco to complete the Hawaii-mainland circuits. The Bell Labs had a third one in their possession. Maury King told me that each apparatus had been manufactured at a cost of $36,000. Each device consisted of two units; one unit was a large invar-steel tuning fork in a massive oven and housing which included a thick layer of balsa wood for insulation; and the second consisted of a specially-built Western Electric generator which drove the circuit switching mechanisms and associated controls. [10]

Maury retired from the Telephone Company and has since passed on. In February, 1981 he called me and said he was moving, and asked if I would like to have the original transpacific “scrambler” used on the overseas circuits, beginning in 1932. I said I would. He said that after seeing my collection he felt that I was the logical person to be entrusted with it. The “scrambler,” which I eventually learned to be the A-3 Privacy Device, had been removed from service by the Hawaiian Telephone Company after many years, had been written off the books, and was destined for destruction. Maury recognized the historical value, acquired it, and took it home where it remained in his basement for many years.
Several months after Maury’s initial offer he sent it to me and it became part of my telephone/radio collection. Maury had built a transistorized amplifier and speaker for the tuning fork for demonstration purposes; it worked just fine. In describing the tuning fork he said that the thick layer of balsa wood provided the insulation for the oven. The 1/4” thick-wall brass cylinder was wrapped with resistance wire in which current flowed under the control of a thermostat to hold the temperature in the fork chamber to 57 degrees Centigrade, ± 1 degree. The capsule was originally filled with dry nitrogen and then was hermetically sealed. The invar-steel fork, with the coils and magnets at one end, resonated at exactly 300 cycles per second, and was used at each end of a radio circuit to control the speed of the associated motor generator. The switches that the motor drove changed the patterns of speech segments every twenty seconds so that anyone picking up the radio signals could make no sense of what was heard without having a similar unit.

The two forks, one in Hawaii and one in San Francisco, at the ends of the circuit, were so carefully adjusted and regulated that they would not differ more than three cycles in a 24-hour period, day in and day out. Each morning a technical operator on duty in the transpacific control room of the Mutual Telephone Company in Honolulu would work with the technical operator in San Francisco via radio to synchronize the tuning forks.

Maury told me that Hawaii’s original Device burned up during its first year of operation. Bell Telephone Labs sent out a spare which was immediately installed.
Figure 4. The drive shaft, located on the left top side of the motor, which turned the frequency-changing switches.

Historical Significance

A question arose in my mind as to whether the message from Hawaii to Washington, D.C. of the December 7, 1941 attack on Hawaii by Japan went through this apparatus. I assumed that most of those who would know had either died or had moved away from Hawaii, but I had to try. So my search began.

About a year ago a good friend, a former employee and retired assistant secretary of Hawaiian Telephone Company, was on Hawaii Island, and we met for lunch. Charlie Penhallow had worked for Hawaiian Telephone for 45 years. During the visit I told him about the "scrambler" that Maury King had sent me and wondered if it was used in the communication from Hawaii to Washington, DC, on December 7, 1941. After I told Charlie the story he looked at me with a very quizzical look and said, "I think you're talking about the A-3 Privacy Device." (That was the first time I had heard the name.) He wanted to know where it was. Charlie said that he was the technical operator on duty in Honolulu on that machine on the morning of December 7, 1941!!!!!! I couldn't believe that I was talking to the one person that probably knew more about it than anyone else.

After lunch I took him to my home and showed him the unit. He identified the Western Electric generator and said he recognized it "as like the device that was in use on the morning of December 7, 1941." I asked Charlie to write me a letter describing what he knew about the A-3 Privacy Device.

According to the Hawaiian Telephone Company's account here is what happened:

"On Sunday morning, December 7, 1941 at 7:55 AM while most of Honolulu was asleep, a wave of Japanese bombers dropped their deadly load on Pearl Harbor signaling the outbreak of hostilities. While the bombs were still exploding, a hurried phone call was received at his
Figures 5, 6, 7. The underside of the A-3 Privacy Device. At the top is the drive shaft emerging from the right, and the complicated machinery which changed the patterns of speech segments every twenty seconds. Below that are the electrical terminal connections located under the motor-generator.
home by Mutual’s Commercial Manager. A Naval officer was at the other end of the line. ‘There is an attack and it’s the real thing. We want some through trunking connections as fast as you can make them.’ It took him but a few seconds to reach the Plant Manager with word to arrange the lines. They drove downtown to the main exchange, while Japanese planes flew overhead and anti-aircraft shells burst on all sides, and arrived there at 8:15 AM.” [11]

By mid-morning, Army and Navy censors took over supervision of all radio telephone as well as overseas cables and radio-telegraph communications. Persons making calls were forbidden to speak in any language but English. They could not mention shipment of goods which could reveal either movement of shipping or inventories on hand. [12]

Charlie Penhallow wrote me his account [13] and the part that he played on that fateful morning:

“You have asked me about the privacy device Maury King sent you a number of years ago when it was no longer going to be needed by Hawaiian Telephone Company. You asked specifically if it had been in use at the time the Japanese dropped bombs on Pearl Harbor on December 7, 1941.

“You showed it to me when I went to your home on January 28, 1993. I recognized it as like the device that was in use on the morning of December 7, 1941. I was the technical operator on duty in the transpacific control room on the second floor of the Mutual Telephone Company building on Alakea Street that morning. My job on Sundays was to
Figure 8. A cut-away picture of the large invar-steel tuning fork which was enclosed in a 1/4"-thick brass walled cylinder. The cylinder was wrapped with resistance wire in which current flowed under control of a thermostat to hold the temperature in the fork chamber to 57°C ± 1°C. The capsule, originally filled with dry nitrogen, was hermetically sealed. This tuning fork, with coils and magnets at one end, put out exactly 300 cycles per second, and was used at each end of the transpacific radio-telephone circuit to control the speed of the associated motor generator. The two forks in Hawaii and San Francisco were so carefully adjusted and regulated that they would not differ more than three cycles in a 24-hour period, day in and day out. The thick layer of balsa wood as shown provided the needed insulation for the oven.

open up the one Honolulu-San Francisco circuit to traffic. Because of the high cost of a call, the business was not enough to warrant keeping the circuit going all night, and was usually shut down at around 2 AM. At about 5:30 AM I would verify with RCA at Kahuku that the transmitter was on the air and would also verify with RCA at Koko Head that the receiver was tuned to the signal coming in from California, and would then contact the technical operator at the San Francisco end and he would line up the two A-3 privacies, which were complicated devices controlled by a 300-cycle tuning fork and were equipped with special band-splitting circuits, which were interchanged every 20 seconds and thus provided a high degree of privacy. The reason for the daily line-up
was to make sure that both the Honolulu privacy and the San Francisco privacy switched channels simultaneously every 20 seconds. Although speech through these machines was intelligible it was nothing to brag about and if a word was being said at the precise moment of the switch a brief chirp could be heard which sometimes caused a customer to say, “What did you say?”

“The device you got from Maury King is probably the A-3 privacy that was in use on December 7, 1941, since I don’t believe the company or anyone in Honolulu had a duplicate, and the subject was not discussed outside the control room. Personnel who knew about it at the company are either deceased or are no longer residing in Hawaii. The instruction books were probably destroyed long ago. I believe the machine was manufactured by Western Electric Company and designed by the Bell Laboratories.

“You also asked if it was through the A-3 that word of the attack got out of Hawaii. I wouldn’t know. Like all the other technical control operators I was required to listen to every word of every call and compare notes as to quality with the San Francisco technical control operator after each call. As a result I heard a few calls which got through before censorship was established in which the subject of the attack was mentioned but as to whether these were the first reports of the attack I have no way of knowing.”

(Signed) Charles F. Penhallow
Figure 10. Cover of the Winter, 1931 Mutual Telephone Co. Telephone Directory for the entire Territory of Hawaii. This was the first directory to include all of the islands in the Hawaiian Group; Hawaii, Oahu, Maui and Molokai. The Island of Lanai was included later.

After reading Charlie’s letter I spoke to him and asked if there were any other circuits that could have been used and his reply was, “not that I know of”.

Hawaiian Telephone Company records show that on December 7, 1941 there were five overseas radio-telephone circuits in use and these were increased by two more circuits by the end of 1942. [14]

In a follow-up on the actual number of circuits in use on December 7, 1941, Charles Penhallow wrote me,

“At the time of the Japanese attack on December 7, 1941 there was only one transpacific radio-telephone circuit in use. But about 1937 AT&T had introduced single-sideband limited-carrier suppression equipment which was installed at the Kahuku transmitter station (on Oahu Island) and at the Koko Head Receiver station as well as the California station. This made it possible to put two calls on each carrier. The original high-powered transmitter was kept in service as a spare but was expensive to operate because it was a double-sideband transmitter using 500-watt water-cooled tubes and the received signal was more subject to selective distortion than the single-sideband equipment and could handle only one call at a time as against four on the other single-sideband equipment.”
Figure 11. Hawaiian Telephone subscribers learned of the inauguration of inter-island radio-telephone service in an article in the 1931 Telephone Directory by President Balch, which also explained how it was accomplished. The article paid tribute to Dr. Lee De Forest in paragraph six as follows: “Returning to the problem of connecting these wire systems (each island system) by the spoken word in spite of the depths of the sea channels separating them, the writer in the year 1912, by authorization of the Board of Directors, went on an investigating tour throughout the United States to ascertain if the project was possible through the medium of deep-sea cable. Again in 1916, the same policy was pursued, and on this occasion, the first possible solution of the question appeared in the then new invention of Dr. Lee De Forest’s 3-element vacuum tube—the forerunner of the present highly developed audion bulb, which was chiefly instrumental in the great advance of Radio during the past decade.” (Continued on page 162)
Figure 12. Listing of the author's father and residential telephone number in the 1931 Hawaii Directory.

The Hawaiian Telephone account of December 7, 1941 answers my question: "Washington learned of the sneak attack by overseas telephone. Switchboards were choked with calls, for it seemed like everybody was trying to talk to someone else to pass on the news, or inquire what was happening. The Army asked Honolulu's two radio stations, KGMB and KGU, to broadcast an appeal to the public not to use the service except for emergency purposes, in order to free the lines for urgent official calls.

Figure 11 (Continued from page 161)

The article went on to say in the final paragraph: "Again in the year 1928, the problem was attacked (after two very careful field surveys of the frequencies between 5,000 and 1,500 kilocycles proved not to be too encouraging) by the company conducting a new series of experiments in the ultra-high frequency spectrum, and on a frequency of 60,000 kilocycles such remarkable results were attained between Oahu and the island of Molakal and Maui that more elaborate tests were deemed advisable. Accordingly arrangements were made for the cooperation of the Radio Corporation of America who likewise had secured promising results in these heretofore unused frequencies. The outcome was that during the years 1929 and 1930 Hawaiian field experiments were jointly conducted which cost this company approximately $18,000, but proved that successful communication could be carried on between the islands of the Territory by ultra-high frequency provided transmitters and receivers were erected on elevations sufficient to overcome to a large extent the curvature of the earth between stations."[16]
A 30% reduction in private messages was immediately effected. This cooperation by the public continued throughout the emergency."[15]

So it now appears that the A-3 Privacy Device, as pictured here, is of historical interest since word of the 1941 attack apparently did go through this machine.

I was not able to get any information from AT&T as to how many A-3 Privacy Devices were manufactured and where they were installed. However, I was referred to Mr. Sheldon Hochhelser of the Bell Telephone Laboratories Archives and he believes that this historical account is correct since much of it is based on the actual first-hand knowledge of those closest to the device, Maurice V. King, Jr. and Charles F. Penhallow.

ACKNOWLEDGMENT

The author would like to thank Charlie F. Penhallow, who retired from Hawaiian Telephone Co., for his cooperation and fine report. Also, Mr. Sheldon Hochhelser of the Bell Telephone Laboratories Archives for his input and opinions. This acknowledges and thanks Mrs. Maurice V. King, Jr. for permission to use the information her husband gave me before his death and also, if Maury were alive, an appreciation for preserving this bit of history for future generations.

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10. Letter from Maurice V. King, Jr. to Roy S. Blackshear, August 26, 1981.
13. Letter from Charles F. Penhallow to Roy S. Blackshear, February
7, 1993, including a report on the A-3 Privacy Device relating to the December 7, 1941 air attack on Hawaii by Japanese forces.

15. Ibid. [1] p82.

Photo Credits: Roy S. Blackshear, 1997

ROY S. BLACKSHEAR
KH6BAI

Born in Hilo, Hawaii in 1923, author Blackshear received his first amateur radio license in 1953. While attending the New Mexico Military Institute in Roswell, NM during the early years of World War II, he would listen to the short-wave bands on a Hallicrafters S20R receiver and write down the names and addresses of American POWs given out occasionally by the Germans, Italians, and Japanese. He passed this information on to the families and received many letters of thanks and appreciation.

After school he served in the Pacific during the war in the 7th and 8th Air Forces. He subsequently continued his education, graduating with a degree in business administration from the University of Hawaii in 1948. He joined the Hawaiian Telephone Company in 1951 and served in various management positions for the next 24 years, before retiring to take over
the family land-management business on Hawaii Island. He retired in 1974 and is now Chairman of the Board of Directors of W.H. Shipman, Ltd.

Roy’s other hobbies include collecting antique radios, phonographs, cameras, and he owns the largest collection of antique telephones in the state. He also raises the rare Hawaiian goose called the Nene, the State Bird of Hawaii. He is an avid photographer.

He is a life member of the ARRL and a frequent attendee at the annual AWA conference. His design for the ARRL Special Services Award Logo contest was one of the four finalists entries.

He resides with his wife Donna at Keaau Beach on Hawaii Island.
Figure 1. The 1936 National Company NC-100, the first of the famous sliding-coil receivers. This relatively scarce receiver is noted by its "art deco" design, with a horizontal red stripe delineating the bands, and alternating silver and black vertical columns. The original main dial was finished with a gray enamel. This particular receiver does not have a crystal filter. (Photo Credit: Niel Wiegand.)
THE NATIONAL COMPANY, INC. — THE COIL-CATACOMB RADIOS AND VARIATIONS ON A THEME...

Lawrence R. Ware
Winter Park, Florida

Introduction

The National Company, Inc. introduced the first of its now famous "coil-catacomb" radios with a brief announcement in 1935, and deliveries of the first radio of the series, the NC-100, started in 1936. The amateur version, the NC-101X, followed soon thereafter.

I have identified over sixty variants of the coil-catacomb design, not counting the battery-model versions, over the production years from 1936 to 1949. Today, few of these radios change hands at over $300, and most can be found for far less. To the radio collector, this is a target-rich environment!

In the beginning the NC-100 was not a great hit. The NC-101X did better with the amateur community, but National initially sold most of the coil-catacomb designs into the industrial and government market. The later NC-100A, with its direct-reading dial, addressed the most common complaint of users, that of having to interpolate the dial readings on the standard NC-100.

Quite a few variations of this series were built in the years leading up to World War II. During the war both National and Wells-Gardner, (using National parts) manufactured a large number of military variations. The majority were built for the US Navy. Large numbers of most of these radios were made, and quite a few survive into the present. National coil-catacomb radios were very common during the salad days of war surplus in the 50s.

I'm going to attempt to trace the family tree for you, and tell you a little something about each member. It is a given for a project like this that we will miss a few, but hopefully all the major branches will be covered. I have included a section, very similar to Raymond Moore's work, which details all the minor differences I'm aware of from version to version.

Those of you, like myself, who collect National coil-catacomb radios will find an almost bewildering array of minor variations. Someday I hope to own a least one example of each of the major family branches, but I'll leave the exhaustive and inclusive collecting of every variation to those with far more time and money than I have.
Figure 2. The cast-aluminum coil tray with the three sets of RF transformers for each band. The steel rack gear is in the front. When closed, each coil is totally shielded from all the others.
In 1936 the National Company, Inc., under the guidance of James Millen, began shipping the first of what was to become one of the most famous radio designs of the golden age of communications receivers, the technically-advanced and mechanically-brilliant NC-100 line. Equipped with an innovative cast-coil catacomb on a gear-driven sliding tray for band switching, the series represented the first truly high-performance communications receiver that did not require plug-in coil sets.

First announced in the 1935 National catalog, this design was to flourish throughout the years of World War II and continue in continuous production until at least 1948, a thirteen-year span that covered at least fifty different variations and thousands of units. By any standards a stunning success, the “coil-catacomb” design radios were used for every imaginable purpose, from living rooms to US Navy ships and submarines to commercial aircraft communications.

National called this innovation the “Movable-Coil Tuning Unit.” Coupled with their “Micrometer Dial” system, commonly called the “PW” dial, they set the standard for repeatable tuning systems.

Notes On Nomenclature And Model Series

All commercial/industrial, amateur and consumer coil-catacomb Nationals of the era had model codes starting with NC-, as in NC-100, NC-100A, etc. Most but not all industrial and military variations had other model codes assigned to them (RAO-, RBH, RCP, etc.) Typical are the RAO-6 and RCK types. There were exceptions (see the NC-127) and some confusing overlapping (see the NC-120.) Also, some other nomenclature codes were sometimes assigned.

The Army, Navy, and Coast Guard all had their own numbering system in those days, and government organizations like the CAA (now the FAA) had yet another. This resulted in an almost bewildering array of model numbers, suffixes and revision numbers. Many military versions had three different model codes assigned: For example, the NC-156-2. This is the model number on the front panel of the radio. Seems simple - right? Yet, the radio was also known as the RBH-2 and as Radio Receiver type CNA-46188.

Fortunately, there are a few general guidelines we can use to help understand these radios. For example, a radio without the “A” suffix (NC-100, for example) prior to the NC-200 has the PW or Micrometer-type dial. An “A” as part of the suffix denotes the “A” series with a direct-reading dial, as with the NC-100A.

An “X” as part of the suffix denotes the addition of a crystal filter (NC-101X, NC-100XA or sometimes NC-100AX, ) except when the radio was not available without one (see NC-200 and later.) There are as
many exceptions to these rules as radios that follow them, but Fortunately
most are military or industrial variations. Some models that were available
with a 200 – 400 kHz band as an option are sometimes referred to as
“LF” versions, as the NC-100ALF, etc. I have been unable to locate any
National factory literature that uses this designation, so I believe it is
either incorrect or highly specialized with a limited use.

From early National literature:

“The Movable-Coil Tuning Unit, heart of the NC-100, is an invention
that makes it possible to shift plug-in coils by the twist of a knob.... .... The
turn of a knob slides the cast aluminum shield along its smooth-running
track, and locks the desired set of coils into exact position directly below
the tuning condenser... Each of the fifteen coils is in its own shielded
compartment, and idle coils are completely out of the way. Rugged, silver-
plated, side-wipe contacts provide dependable circuit connections... Air
dielectric condensers are used for trimming circuits and R-39 is used for
insulation.... The calibration of the NC-100 is permanent and precise...
...Vital to the precision of the tuning system are the geared tuning condenser
and the Micrometer dial, with readings direct to one part in five hundred....”

This was quite a design achievement for 1935. Frequency accuracy
was good, but repeatability was superb for the time. If you logged the
BBC at 410 on the dial, it was at 410 night after night. Comparing this to
other receivers of the day, only the HRO (also with a PW Micrometer
dial) could even come close.

From the 1935 National Company, Inc. Catalog, page 17:

The NC-100 Receiver

A new receiver, to be known as the NC-100, is now in preparation. This
new receiver will employ a very advanced type of tuning system. Coil ranges
will shifted by a knob on the front panel, but no switch will be used. Instead, a
set of plug-in coils, each in its own shield can, will be moved into position and
plugged into the circuit by a built in mechanism. This system is admittedly the
best from the electrical point of view, but its mechanical difficulties have
discouraged its use in the past. The NC-100 receiver presents so many unusual
features that it is not practical to make a complete description in the catalog,
and consequently we are preparing a special booklet describing the receiver in
detail. We plan to make first deliveries of the new receiver during December,
and expect the price to be under $100.00. In the meantime, those desiring a
copy of the booklet are invited to write us (give name and address) and we will
forward a copy as soon as it is off the press.
From late 1936 National Company advertisements:

Announcing: The National NC-100 12-Tube Superheterodyne

The NC-100 is more than a newly-designed receiver, it is a new invention! Although coil ranges are shifted easily and quickly by the twist of a knob on the front panel, no coil switch is used. Instead, an ingenious mechanism moves efficient plug-in coils into position close to the tuning condenser and tubes, and plugs them in. Each of the fifteen HF coils is shielded in heavy cast aluminum, each is of a high-Q design, each has low-loss insulation, and each has its own individual air-dielectric padding condenser. Idle coils are completely isolated. Leads are short. Calibration is permanent. For the first time the uncompromised efficiency of plug-in coils has been combined with the convenience of the coil switch.

The precise and efficient Movable Coil Tuning Unit is just one of the many details that make the NC-100 so outstanding. Every tube in the NC-100, and there are twelve of them, contributes its full share to the remarkably high overall performance. The circuit employed on all ranges consists of one stage of RF, separate first detector and high frequency oscillator, two IF stages, a bias-type power detector, and a transformer-coupled push-pull output stage. Maximum undistorted audio output is ten watts. A separate tube is employed to provide amplified and delayed AVC action, and a separate beat oscillator is included for CW reception. A built-in power supply provides all voltages required, including the speaker field.

But equal in importance to the circuit and tube layout is the long list of small details that make the NC-100 the superlative receiver that it is. There is no substitute for quality. The heavy cast-aluminum coil shield, the thorough use of low-loss insulation, the high-Q coils, and the air-dielectric padding condensers, as well as a host of smaller details ranging from silver-plated contacts to the non-microphonic speaker cabinet, all contribute to high intelligibility on weak signals.

Particular attention has been paid to the convenience of the operator in the NC-100. Swift control of every function of the receiver is at your fingertips. The Movable Coil Tuning Unit permits instant selection of any one of five coil ranges, ranging from 540 kc. to 30 Mc. Matching the accuracy of this precision unit is the Micrometer Dial, direct reading to one part in five hundred, and having an effective scale length of twelve feet. The tuning of the NC-100 is as smooth as its logging is precise.

A 6E5 tube acts as an indicator both when tuning and when using the RF gain control for signal strength measurement. (Author’s note: The tuning eye system was replaced in all but the earliest versions by a balanced-bridge type S-meter circuit.) Panel switches permit optional use of automatic volume control and of the CW oscillator, and provide
for cutting the plate voltage during periods of transmission. In addition to RF gain, an audio gain control and a tone control are included. These together with the (optional) single-signal filter give the operator complete control of receiver characteristics. Even the phone jack has received its share of attention, for it has been carefully located so that the phone cord will interfere as little as possible with the manipulation of controls and the use of the operating table.

Advantages Over Plug-In Coils Sets And Early Band-Switched Radios

No discussion of the NC-100 family would be complete without evaluating the pros and cons of the “Movable Coil Tuning Unit” or coil catacomb against the competing designs of the day. The competition can be summarized as follows:

A. Plug in coil radios like National’s own HRO.
B. Bandswitched radios like many of the early Hallicrafters.
C. Single-band or fixed-frequency radios in general.

The contemporary National HRO receivers had slightly better book specifications, but minor differences in performance usually disappeared into the noise in the real world. The HRO could be ordered with custom, special coil sets by any customer willing to pay for them. In addition, the ability to have both general coverage and amateur-band bandspread coil sets used in the same radio did confer greater flexibility on the HRO until the introduction of the NC-200 series, around 1940. Both radios used the Micrometer (PW) tuning dial and both had very good performance for their time. Unlike the NC-100 line, HROs of the time also required an external power supply.

Most early bandswitched radios suffered to some extent from stray resonances and tuning peaks and valleys. These problems were much more prevalent in the lower-cost entry-level equipment sold to many new amateur-radio operators and short-wave listeners. Few if any of the competition ever came close to matching the repeatability of the custom-built National coil catacombs, tuning condensers and Micrometer dial. Even National’s entry into the low-cost “starter” radio end of the market had good performance. (See the NC-80X/81X.)

Some single-band and fixed-frequency radios of the era exhibited equal performance. However, even those often lost out in large contracts to modified coil-catacomb-based designs. (See the AGR series.)
For many years, we have used only "plug-in" inductors in National high-frequency receivers, because only by so doing could we build into these receivers the outstanding performance for which they are so well known. We have, of course, realized that a switching arrangement would be more convenient to the operator. Inasmuch, however, as the use of any switching arrangement that we know of would have resulted in a definite decrease in performance, we have steadfastly continued to use plug-in inductors. In the NC-100 receiver, we have now reached a design of plug-in inductor that is in every way equal to the switch in convenience, and at the same time retains all of the superior electrical and mechanical advantages of the original plug-in inductors.

Overview Of Family Tree And Production Timelines

1935: First mention in catalog of new receiver to be released.
1936: October: Full-page advertisements for the new NC-100 in Short Wave Craft, Radio Craft, and other popular magazines of the era. (These continued through December.)

Figure 3. Approximate years of manufacture of the National coil-catacomb receivers.
1937: February: *QST* ad for NC-101X amateur-bands-only version of NC-100; also has crystal filter, still has tuning eye tube. Price $125.00. Sometime in early 1937 about 100 type RCD radios were made under a CAA contract.

June: RCK type reported made as part of VF Radio Equipment No. 6736. (Pvt. communication)

October: First RCE types produced for CAA, Order # 38-2832 and #38-2833.

October: RCK type produced for CAA by Westinghouse, Order # 38-2833.

1937 National catalog lists the NC-100 (tuning-eye version) complete with tubes and speaker at $120.00. The battery model is $110.50. Adding the optional crystal filter brings the price to: $142.50.

Also listed: The NC-80X at $88.00 complete with tubes and speaker. The NC-81X is available at the same price.

1938: Production of retail (standard) version of NC-100 ends. Production of retail (standard) version of NC-100A starts. Production of Navy RAO series begins with first RAO (no suffix) model.

1939: May: James Millen announces that he is leaving National and forming his own company, the James Millen Company, to manufacture and sell radio equipment:

June: First RCF types produced for CAA, Order # 39-2748

October: James Millen Company first ad in *QST* and catalog appears.

October: First RCH types produced for CAA, Order # 40-1760.

Production of NC-80X/81X discontinued

Production of NC-101X ends

Production of NC-100XA starts.

1940: October: NC-200 introduced to replace NC-101X among others. December: R-115 Coast Guard contract TCG-23454.

Production of NC-200 begins.

1941: May: R-116 Coast Guard contract: TCG-33675.

June: RBH Navy contracts for type CNA-46144: contract 8766. (NXsr-8766?)

September: RC-120 Coast Guard contract: TCG-33991.

1943: 1943 *ARRL Handbook* (catalog section) lists both the NC-100A and NC-101XA along with options. Several versions (NC-101X, NC-101XA) are listed as “temporarily discontinued” because of the war.

Production of NC-200 ends.
Production of NC-2-40 begins (replaces NC-200).

**1944:** June: RAO-6 Navy contract: NXsr-38306.
NCRM experimental diversity system produced late 1944- early 1945.
Production of NC-2-40 ends.

**1945:** January: RAO-6 Navy contract: NXsr-38306.
May: RAO-7 Navy contract: NXsr55614.
October: Type RCP made for CAA, Order 46-1467.
NC-100A still in 1945 catalog, at $220.00 with speaker.
NC-100XA with speaker is $261.25.
NC-200 still in 1945 National catalog at $265.83 W/O speaker.
1945 Catalog has a picture of the NCRL and very brief mention. (P-21)
Experimental triple diversity NC-127D system built. Only one system believed made.
Production of NC-2-40C begins.
Production of retail version of NC-100A ends.

**1946:** April: War surplus has become available. In a Newark Electric Company ad, a National NC-100-ASD, complete with speaker in cabinet, is $115.00. Spare parts kit is $4.95.
Production of NC-2-40C ends according to Moore’s 4th. It is still in the 1946 National catalog, along with the model NC-2-40CS, which has a low-frequency 200 – 400 kHz band.
Production of NC-2-40D begins according to Moore’s 4th.

**1947:** Production of NC-2-40C ends (according to SRPP).
Production of NC-2-40D begins (according to SRPP).
May: James Millen unveils the "Designed For Performance" DFP201 and DFP501 at a Chicago trade show.

**1948:** February: Type RCQ made for CAA, Contract # CCA-26227.
August: CAA ordered field retrofit for RCP radios currently in service. Main change was addition of noise-limiter circuit. The modification order and instructions, (CAA Communications Engineering Division Circular # 41) was issued on August 17, 1948.
NC-2-40D still in National 1948 catalogs, at $241.44 with matching speaker.
Production of NC-2-40D ends according to SRPP.

**1949:** Production of NC-2-40D ends according to Moore’s 4th.
THE MAJOR BRANCHES

The NC-100

The NC-100 receiver is a twelve-tube superheterodyne covering all frequencies, from 540 kHz to 30 MHz, in five ranges. The design in general consists of one RF stage, a separate first detector or mixer, a high-frequency oscillator, two stages of IF amplification, a bias-type power detector, and two stages of audio amplification. Another tube is employed for amplified AVC action. A separate beat-frequency oscillator (BFO) tube and circuit is included.

Civilian versions usually used a push-pull audio output design, while military versions usually had a single-ended output configuration.

A built-in ac power supply is included (except battery models) which provides all voltages required, including excitation for a speaker field coil.

From the NC-100 manual:

Controls:

The main tuning dial is located near the center of the front panel and operates the three-gang tuning condenser. This dial is of the multi-revolution type operating through a spring-loaded gear train having a step-down ratio of 20 to 1. In tuning across any one coil range, the dial makes ten complete revolutions and since its diameter is four inches, the equivalent scale length is approximately twelve feet. There are fifty divisions about ¼” apart around the circumference of the dial and the index numbers are changed automatically as the dial is rotated by means of an epicyclic gearing, so that the calibration is numbered consecutively from 0 to 500. The index numbers are actually changing continuously, the shift occurring at the bottom of the dial where it is not ordinarily visible.

Through this mechanism it is thus possible to obtain a continuous dial reading from 0 to 500, with the result that all signals are well spread out on the scale, making tuning and logging both convenient and precise.

The tuning system is so arranged that the dial reading increases with frequency, as shown by the calibration curves.

Immediately below the dial is the range-selector knob, which actuates the coil-changing mechanism. This knob must be rotated approximately one turn to change from one range to another. The arrangement is unique in that each individual coil is completely shielded from all the others and that only the coils actually in use are in any way connected to the circuit.

This automatic “plug-in” coil system is extremely efficient. Dead spots, often occurring when using unshielded coils in conjunction with a switch are, of course, completely absent and the particular coils in use
are in the best position both mechanically and electrically. The relatively large movement of the coils, when changing from one range to another, makes possible the use of rugged contactors of such construction that trouble-free performance is assured.

The five coil ranges are marked on the front panel in a horizontal line directly over the range selector knob. Each of the range markings has a small window in back of which an indicator appears when that particular coil assembly is plugged into the circuit.

Starting at the left-hand side of the front panel, the uppermost knob is a tone control for varying the frequency characteristic of the audio amplifier. When the control is rotated to the extreme counter-clockwise position, high-frequency cut-off occurs at about 1500 cycles. In the mid-position the characteristic is flat from 50 to 10,000 cycles. At the extreme clockwise position, low-frequency cut-off starts at 300 cycles, and the characteristic rises (about 6db) between 1000 and 5000 cycles. When receiving strong signals free from interference, best audio quality will be obtained with the tone control set to zero. When receiving fairly weak signals through considerable interference, it is often helpful to retard the tone control so that noise will be reduced in relation to the signal.

Below the tone control is a combination switch. In the extreme counterclockwise position the receiver is turned off; in the mid-position all heater circuits and the rectifier are turned on but no B voltage is
applied; in the clockwise position the B+ is turned on to place the receiver in operating condition.

There are two insulated terminals mounted at the back of the receiver chassis, which are connected in parallel with the B+ switch. They are intended to serve as a convenient means for connecting a relay for automatically turning the receiver on and off.

To the right of this switch is the manual RF gain control. This control is ordinarily used only for receiving CW signals but may, of course, be used as a conventional volume control if the operator does not wish to use the AVC system. With the automatic volume control circuits in operation, as explained later, the RF gain control is limited in its action and is useful principally in adjusting the maximum sensitivity of the receiver.

For instance, if local noise and static level is high, the RF gain control need only be advanced to the point where the disturbance is just plainly audible. Signals may then be tuned in with the AGC on but inter-channel noise will not be objectionably high. It will be found that after a signal is tuned in, further advancing the control has no effect on output, inasmuch as the AVC characteristic is practically flat.

To the right of the range selector knob is the audio gain control, the primary purpose of which is to control volume (on either headphones or speaker) when using AVC. When using the manual RF control, the audio gain should not be retarded too far. If for instance, it is set below three or four on the scale, audio output will be limited to the point where IF overload may occur before maximum output is reached.

The knob at the lower right-hand corner of the front panel is a combination switch having three positions. In the counterclockwise position the AVC circuits are in operation; mid-position the AVC is turned off; in the clockwise position the CW oscillator is turned on, the AVC still being off.

Above this switch is the CW oscillator vernier tuning control, which varies the frequency of the oscillator over about 10 kc.

Near the tuning dial is mounted a pilot light and an electron-ray tuning indicator. The pilot is lighted at all times when the ac switch is turned on, but the tuning indicator is lighted only when the B+ switch is on. The purpose of the tuning indicator is to provide a visual means of accurately tuning phone signals. The shaded portion of the tuning indicator normally covers a sector of about 90 degrees. When tuning in a signal, the shaded area will become smaller, correct tuning being indicated by the smallest angle....

On models of the NC-100 having the crystal filter (NC-100X) two additional controls are provided, and these are mounted at the right-hand side of the tuning dial. The uppermost knob is the selectivity control of the crystal filter. With the filter in use, minimum selectivity will be found with the pointer nearly vertical. Rotating the knob in either direction
from this position will increase selectivity. When the filter is not in use, the knob should be set at the point giving maximum volume and sensitivity.

Immediately below the selectivity control is the phasing control and crystal filter switch. Turning this control to zero disconnects the filter; at any other setting between 1 and 10, it acts as a phasing condenser for balancing the crystal bridge circuit, eliminating heterodynes, etc.

The NC-101X (first amateur model)

On May 11, 1976 James Millen wrote a letter to William Orr of Eimac in which he briefly discussed the NC-101X. Some excerpts from the letter:

"... But I do well remember traveling around the country in the early NC-100 days visiting ham dealers in the daytime and attending local ham club meetings in the evenings promoting the NC-100 sales. The reaction was that no matter how intriguing the band-switching construction, (Author's note: JM is referring to the coil-catacomb design) the styling, (front panel) the lack of band-spread tuning and the price, while fine for the new breed of "short wave listeners" was just not what the ham wanted.

"As well as I can recollect, this point was hammered home to me at an impromptu meeting with a group of Pittsburgh hams one evening at the old Cameradio Amateur Supply Co. and then, again, later that same week in Chicago with another group..."
"... In the back of their pioneer ham supply house, CHIRAD, on hotel stationery, the sketches and notes for the evolution of the 101 from the 100 were completed and sent to Malden before I ever got back to North Reading and the lab."

William Orr reported (CQ, October, 1978) that:

"It appears that the problem was turned over to three amateurs: Dana Bacon (W1BZR), Calvin Hadlock (W1CTW) and Tom Leonard. These three, under the supervision of Phil Eyrick, a machinist-model maker, turned out a prototype NC-101X receiver in short time. The first commercial receiver for amateur-band only reception."

Thus, the NC-101X was born...

Later in the same letter, JM refers to the later "A" model with direct reading dial:

"...The more conservative front panel of the 101, plus the desire to incorporate a direct-reading calibrated scale, led to the 100A with the length of the telescoping dial pointer controlled by the coil catacomb position and consequent operating band."

The NC-101X is essentially the same radio as the NC-100X, the only difference being the amateur-band-only tuning by the use of a different main 3-gang tuning capacitor. Early models have a tuning-eye tube, while later versions have a S-meter. I do not believe this radio was available without the crystal filter.

From the National Special Instructions for the NC-101X receiver:

The NC-101X is a special model of the NC-100X receiver, employing the same circuit, etc., but covering only the five low-frequency amateur bands. Each of these bands is spread out over the major portion of the dial and, as shown by the calibration curves, each band starts at 50 and ends at 450. The curves are accurate to about 0.25% of the operating frequency.

The National NC-100A Series:

When introduced in 1938 the NC-100A specifically addressed what was perceived as the major failing of the NC-100, the lack of a direct-reading dial. The NC-100, while doing well in the industrial market, had been a disappointing sales failure for National in the rapidly growing short-wave listening (SWL) market in America. The "A" line directly addressed the most common complaint by incorporating both a new
Figure 6. The NC-100 XA receiver, with the direct-reading dial. The X signifies a crystal filter.

Figure 7. A close view of the NC-100 A dial calibrations.

Figure 8. One of the coil assemblies.
direct-reading dial system for frequency, and a moving pointer to indicate the selected band. Somewhat taller than its predecessor, the 100A also included the much easier-to-use S meter, replacing the tuning-eye. As far as I’m aware, all “A” models also incorporated National’s “noise peak-limiter” circuit. NC-100AX models included crystal-filter circuits.

A number of variations of the NC-100A were built. They were available as the X version with a crystal filter, and with a LF band (200 - 400 kHz) instead of the standard 540 - 1,300 kHz “low” band.

There were also at least two versions of the battery models. The first needed external B+ and 6.3-volt filament power supplied, and the second contained an internal vibrator power supply and required only six-volt dc power to operate.

The direct-reading dial system had five bands or scales calibrated for the five sets of band-tuning electronics in the coil catacomb. The band-change knob moved the coil catacomb along the internal rail to select the appropriate band. The direct-dial system also was equipped with an auxiliary numerical dial with 100 divisions on it. The dial made ten revolutions as the tuning capacitor rotated through 180 degrees. This allowed for logging and a very high repeatability, with a direct reading to one part in a thousand.

The basic NC-100XA design was incorporated into many Navy variants (see the RAO Series.)
The NC-200 Series:

The NC-200, developed about 1940, was the first National coil-catacomb radio to combine both tuning and band selection into a single main control. Called a “Universal Communications Receiver” in the National manuals, where earlier models used two large control knobs, one for band switching and one for tuning, the NC-200 had a single, integrated frequency-control system. “Pulling” the main control out engaged the bandswitching function and allowed the operator to select any of six general-coverage or four amateur-bandspread ranges. Pushing the main control inward linked the tuning drive to the tuning capacitor and the direct-reading dial.

Needing to manufacture only one receiver for both, the general coverage and amateur markets offset the added complexity of both the main control and far more complex coil-catacomb. SWL (short wave listening) was a popular pastime during the war years, so the ability to use the radio for both SWL and amateur radio should have been a strong selling point. The radio used a good sounding push-pull audio output system (two 6V6s), and came complete with a crystal filter and matching speaker in a more modern and consumer-oriented case than the typical back-wrinkle finish of the earlier National receivers. Large “cooling” louvers on the sides gave it a very modern look.
With the exception of the new tuning mechanism and ten bands in one radio, the NC-200 was a conventional National superheterodyne design. The series noise limiter and Lamb-type crystal filter were included. The NC-200 evolved into the NC-2-40, which became the NC-2-40C, -CS and eventually the NC-2-40D, the last of the line for National coil-catacomb receivers.

The National NC-2-40 Series:

The NC-2-40 series radios are conventional twelve-tube superheterodyne designs with continuous-frequency coverage from 490 kHz to 30 MHz. The receiver was designed to allow the amateur operator to use bandspread on the 80, 40, 20, 11, and 10-meter bands without sacrificing performance in general-coverage applications.
The -2-40 series were extremely sensitive receivers with a specified output of one watt of audio for a one-microvolt antenna input signal. National touted high-frequency improvements based on molded polystyrene coil forms, Isolanite condenser parts and tube sockets, etc.

Most of the -2-40 series included cadmium-plated chassis to provide positive grounds and better conductivity as well as a nicer appearance.

**The National “Airways Ground Receiver” (AGR) Series**

From 1937 to 1948 the government bought many modified NC-100 (non-A) series radios for aviation-ground-station related use. The CAA NC-100 variants are known by a series of model codes. All have three letters (RCD, RCE, RCK, RCL, RCP, etc.) and reflect changes in the basic design and also some by the government sub-contractor.

All of these radios started out life as National NC-100s. National was well known as a primary supplier of both components and sub-assemblies to many other radio companies. It would only have been a small step for them to move into supplying complete radios to other government contractors. Perhaps the non-converted radios already belonged to the CAA? I have been unable to locate any records that could shed light on this aspect of the AGR’s history.

An unresolved question about the NC-100-based “Airways Ground Receiver(s)” is: How many were originally built and sold to the CAA by

---

**Figure 13. Coil tray and coils for the NC-200 receiver.**
National (the RCD Series) and how many NC-100 radios were modified by other contractors? The available records are inconclusive, but it appears that National worked very closely with the identified vendors for the AGR series and may have done a large portion of the modifications made to these radios in-house, simply allowing the primary contractor to attach data plates to the radios.

**CAA Versions**

Later versions started out life as type RCE, RCF, RCH, RCK and RCL radios and were then modified into type RCP and RCQ radios under multiple “retrofit” contracts.

Both my type RCPs started out life as type RCK radios, and all the IF transformers are ink stamped “RCK.” All of these radios bear strong resemblance to their NC-100 origin. All have the National sliding-coil catacomb design with the white or orange band marker which shows through the respective hole in the front panel. All have the famous PW-type dial, geared tuning drive and the National three-section tuning capacitor. There are several extra controls related to fixed-frequency operation and the CONS (carrier-operated noise suppression) system on the front panels of most of the CAA variations. Most also have a “dial lock” stud located next to the PW dial. Some earlier versions have a sharp/broad control on the front panel for changing the IF band-pass characteristics.

As you can see, the records I have are still missing quite a bit of information. I have manufacturers' manuals for types RCF, RCL, RCP and RCQ and at least some information such as schematics on several of the others. I've noted that Moore’s 3rd refers to several of these radios.
Figure 15. The CAA model RCK-1 receiver.

### Known variants:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Contract/Order codes</th>
<th>Contract/Order date</th>
<th>High S/N reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCD</td>
<td>Order # 37-7383</td>
<td></td>
<td>101</td>
</tr>
<tr>
<td>RCE</td>
<td>Order # 38-2832</td>
<td>?</td>
<td>478</td>
</tr>
<tr>
<td>RCE</td>
<td>Order # 38-2833</td>
<td>October 1, 1937</td>
<td>187</td>
</tr>
<tr>
<td>RCH</td>
<td>Order # 40-1760</td>
<td>October 19, 1939</td>
<td>?</td>
</tr>
<tr>
<td>RCF</td>
<td>Order # 39-2748</td>
<td>June 30, 1939</td>
<td>118</td>
</tr>
<tr>
<td>RCK</td>
<td>?</td>
<td>June 30, 1939</td>
<td>235</td>
</tr>
<tr>
<td>RCL</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>RCP</td>
<td>CCA-24653 Order # 46-1467</td>
<td>October 30, 1945</td>
<td>825</td>
</tr>
<tr>
<td>RCQ</td>
<td>CCA-26227 February 5, 1948</td>
<td>404</td>
<td></td>
</tr>
</tbody>
</table>

as NC-100A-based units. This is incorrect. All were based on the original NC-100 (non-A) PW-dial design. Moore corrected this in his recently released 4th edition.
The earliest known contract for Airways Ground Receivers seems to be Order # 37-7383, not long after the NC-100 started coming off the National production lines. National built this radio, the RCD, directly, unlike many of the later versions that were modified by other contractors.

The RCD is the only model in the series that I'm aware of with both a crystal filter and push-pull audio output circuits. Later models had no crystal filter and only a single-ended output circuit. With the exception of the 200 - 400 kHz low band, the RCD seems to be electrically identical to the early NC-100X, complete with the 6E5 tuning eye tube. Appearance wise, it looks identical to the early NC-101X amateur receiver.

Contractor modifications that seem to have been made to all the later CAA radios include an “Interchannel Noise Suppression” (INS) or “Carrier Operated Noise Suppression” (CONS) system. This was an interesting early squelch system controlled by a relay in one of the tube plate circuits, usually a 6F8.

All of the later series radios seem to have been modified for fixed-frequency operation by allowing the high-frequency local oscillator to operate under crystal control. Typical “channel” frequencies appear to be 3,025, 3105, and 6120 kHz.

**Typical specifications:**

Five bands: 200 - 400 kHz, 1.3 - 2.8 MHz, 2.7 - 6.4 MHz, 5.9 - 14.4 MHz, and 13.5 - 30.0MHz. IFs are 455, or 457 kHz, with variable bandwidth modification.

Unusual tone-control circuit, (steep audio roll-off below 100 Hz and above 2 kHz.) Fixed-frequency-operation option, and INS or CONS system. No S meter or crystal filter seem to have been used. This is consistent with reports that the radios were commonly used in remote locations.

A typical tube line up in these radios (this one is for the type RCL) would be:

6K7 RF amplifier, 6J7 mixer, 6J5 high-frequency oscillator, 6K7 1st IF amplifier, 6K7 2nd IF amplifier, 6C5 detector, 6F8G 1st audio amplifier and squelch, 6J7 beat-frequency oscillator, 6J7 AVC amplifier, 6J7 CONS amplifier, 6V6 audio output, 80 rectifier.

**Variable bandwidth I.F. Transformers**

Many of these radios were built with unusual modified National IF transformers. Besides the normal primary and secondary windings these also have a third (tertiary) winding used to affect the coupling coefficient of the transformer. This allowed two different bandwidths (sharp or broad) controlled by a
switch which connected one end of the tertiary winding to ground. Late models of these radios (RCP, RCQ) had this feature (switchable bandwidth) removed and the transformers hard-wired, as either sharp or broad.

The tertiary windings on these are one turn above the upper winding in the IF can, and one turn below the lower winding in the can, connected to the shield can (ground) at one end and either an external wire or a spring contact on the other.

**Series Noise Limiter Modification:**

In the type RCQ the 6C5 was replaced with a 6H6, with the second diode in the 6H6 used for National’s “Series Noise Limiter” system. Some RCPs also received this modification.

There was a CAA-ordered field retrofit for RCP radios currently in service to install the noise limiter circuit. The modification order and instructions, (CAA Communications Engineering Division Circular # 41) was issued on August 17, 1948.

Later models went through a number of small changes as problems with the interaction of IF bandwidth, RF gain, and CONS set points were addressed. The entire 1948-contract RCQ incorporated National’s “Series Noise Limiter” design, which had first appeared in the NC-100A in about 1942.

The primary use of these radios seems to have been in a fixed-frequency mode. Perhaps the main airport “call-up” frequency for the tower? Close examination of the design shows extra effort was made to insure receiver stability. Temperature coefficient of components in the local oscillator, IF chain and RF front end were selected and specified with frequency stability clearly in mind. The early CONS squelch system, coupled with the unusual audio filter in the radio, clearly point to clarity and reliability of voice communications as a design priority. CONS allowed the radio to effectively ignore random background noise, yet produce a high-level signal out when an approaching air crew called.

**Excerpts from the type “RCP” manual:**

... Designed for use at Civil Aeronautics Administration Airway Communications Stations.

... The high-frequency oscillator has been modified so that it may be made either crystal controlled or tunable by means of a switch on the front panel.

... to facilitate the AVC and CONS circuit... the second-detector circuit has been changed...

... The audio-amplifier circuits of the receiver have been redesigned to
give a frequency characteristic which is fairly flat from 100 to 2000 cycles and falls off slowly to give a response of more than 15 dB down at 5000 cycles.

Excerpts from the type “RCQ” manual:

... This receiver was originally a Type RCK or RCL receiver. The type designation was changed to RCQ at the time these modifications were made to distinguish it from its original type.

... The AVC circuit has been completely changed to correct several conditions. Before modification, the AVC action was proportional to the peak-signal input and thus was unduly affected by static crashes and modulation peaks. This feature was considered undesirable, therefore the AVC circuit was changed so that it responds to the average carrier input.

... The CONS circuit has been changed.... This modification has been made because the CONS control was so badly interlocked electrically with the RF gain control that it had to be reset each time the RF gain control was changed.

Unusual Output Panels

All of the later units have an unusual terminal-board output-connector panel on the rear. This is one of the easiest ways to quickly identify one of the AGR-series radios.

Figure 16. Rear view of the RCK, showing details of the output panel.
Labeled output terminals included: "monitor" and "600 ohm," as well as speaker terminals. This would allow the audio to be easily piped into a local audio system for output on monitor speakers throughout the building or tower.

All of the CAA radios except the very early RCD also have single-ended 6V6 audio outputs. (This was common in military versions of the NC-100 and NC-100A, but the civilian and amateur versions usually had push-pull output circuits.) As you can see, these radios contain some interesting engineering changes from the standard NC-100.

Production contracts that I have at least some information on point to production runs from 1937 to 1948. Contracts over an eleven-year span tell us that they filled a real need in the pre- and post-WW II aviation arena.

These radios show up from time to time at ham fests in the $50-100 price range. With good performance, and a ton of interesting history attached to each one, I rate them as a definite "buy" for any National collector.

The RAO series: (RAO, RAO-1 to RAO-9)

Born in the days of World War II, the US Navy RAO series of National NC-100As have some unique features that make them quite interesting.

All but the quite rare RAO (no suffix) and RAO-1 have an extra RF tuning stage ganged onto the back of a modified NC-100A chassis. This extra sub-chassis is attached with a combination of bolts and spot welds. Other changes included single-ended audio output, provision for external dc power as well as 115 Vac, and several variants with Panadaptor outputs.
The extra RF-preselector stage common to most RAOs has a lot of interesting speculation and misinformation surrounding it. It is commonly believed these preselector stages were added to many Navy radios to prevent enemy forces from DFing (direction finding) the local oscillators in the radios themselves.

The E.H. Scott Radio Company apparently started this with a series of radios equipped with shielding and preselector circuits for marine use. I have been told that they advertised the unique features of the radios in trade journals of the era, suggesting that radios without these features could get a ship sunk by enemy U-boats!

However, a check of published information reveals no evidence that Germany or Japan ever claimed a kill based on DF of local-oscillator circuits. They did report kills based on locating convoys and other shipping from two-way communications (ship-to-ship and ship-to-shore messages.) And, also, many from the reception of spotting reports transmitted from Axis long-range patrol aircraft.

The Navy specifications of the time were very strict in this regard. Several of the RAO series Navy manuals state that oscillator radiation must be below 400 micro-microwatts as measured at the antenna terminals. That is less than 400 pico-watts of radiated leakage!

Another common belief is that these preselector circuits actually served a much more important, but far less exciting purpose. Warships, since the dawn of electronics communications, have always been an extremely high-intensity electromagnetic-field environment. This is even more true
today than during the years of World War II. Even then, multiple transmitters and receivers for all types of uses had to coexist without interference to each other.

_Battleship Sailor_, by Theodore C. Mason (Naval Institute Press, 1982) is the non-fictional story of Petty Officer Mason’s life as a radioman aboard the battleship _California_, leading up to its sinking during the air attack on Pearl Harbor by Japan. While this book has little to say about the specific radios used in warships of the time, it does go into quite a bit of detail about operating procedures, and how the communications systems on a fleet-command battleship were used. Multiple transmitters and receivers were expected to coexist constantly. In fact, the descriptions of radio operations by the author would be impossible if the onboard transmitters were prone to interfere with onboard receivers nearby.

When you consider that most if not all of such a warship’s antennas were in close proximity to each other, the ability of any receiver to reject very strong nearby signals becomes quite critical! High levels of local-oscillator leakage could also play havoc with other nearby receivers.

Speculations concerning the reason(s) behind the stringent leakage specifications of the time continue to this day.

**General information that applies to all versions:**

Each of these radios was originally furnished with the following:

1 Type CNA-10125 Mounting Base or equivalent.
1 Set of Spare Parts.
1 Instruction manual.

Units also had a “Tender” or “Depot” set of Spare Parts furnished for every ten (10) field units. This was a more complete kit used for maintenance on radios that could not be field repaired.

Some typical weights, (from my RAO-6 manual) included:

- **Radio Receiver:** 75 lbs.
- **Mounting Base:** 5 ¾ lbs.
- **Spare Parts Kit:** 46 lbs.
- **Tender Spare Parts Kit:** 78 lbs.

Typical Dimensions, (for units with the preselector):

- **Depth:** 17 ¼”
- **Height:** 10 21/32”
- **Width:** 17 3/16”
- **Dimensions (crated):** 36 ½” X 22 ¼” X 17 ¼”
All RAO-series radios were built on the same basic copper-plated steel NC-100A chassis.

Typical Frequency coverage and bands:

- Band E: 540 - 1,300 kHz
- Band D: 1,300 - 2,800 kHz
- Band C: 2,800 - 6,400 kHz
- Band B: 6,400 - 14,000 kHz
- Band A: 14,000 - 30,000 kHz

Even within the same model number differences exist. For example: Most Navy RAO-series manuals specify a 6K6 as the audio-output tube. Many have instead a 6V6 or 6F6 installed, and that number inked near the tube socket. Minor undocumented changes of this nature seem to have been quite common during the war years in the RAO series.

Several of the RAO series have a "Panadaptor" output connector located on the rear of the radio. The SO-239 female connector appears to be standard and correct for this application. (Note that the antenna connectors were either binding posts or an odd military coax connector, so a SO-239 as an antenna connector marks a modified, non-correct radio. Also, the Panadaptor connectors have B+ voltage applied to the center pin so be careful connecting anything to these outputs.)
RAO series with Panadaptor outputs include:

**RAO-2/NC-120**
Some RAO-6s (Navy field modification that may or may not be installed.)
**RAO-7**
(See detailed alphabetical listing for more information.)
**RAO-9**

![Image of a radio receiver and speaker](image_url)

**Figure 20.** An RBH receiver with matching speaker. This started life as an NC-156, and is so labeled. There is no added preselector.

The NC-156, NC-156-1, NC-156-2 or RBH Series:

- NC-156   (RBH)
- NC-156-1 (RBH-1)
- NC-156-2 (RBH-2)

The first of the series, the NC-156/RBH (no suffix,) is a modified NC-100AX design without the extra RF stage of the later models. The radio was also known as a type CNA-46144. Model 156/RBHs all use an unusual 1560-kHz IF scheme instead of the far more common 455 kHz design of most of the other coil-catacomb receivers. All also had the same unique set of available bands: 300 – 1200 kHz for the lowest band, and 1.7 – 16 MHz for the other four.

The NC-156-1 and NC-156-2, (RBH-1 and RBH-2) series are virtually identical to the RAO-3/4 series of radios. They, like the RAO-3/4, have an extra RF stage ganged onto the rear of a standard NC-100A chassis. The only differences are in the local oscillator and IF circuits.
The 156-1 and 156-2 also use the unusual 1560 kHz IF scheme, instead of the far more common 455 kHz design of the RAO series.

Electrically, the HFO runs at a larger offset, 1560 kHz instead of the usual 455 kHz, from the tuned RF incoming signal. This results in minor changes in available tuning ranges. The crystal filter seems to be a hybrid design, falling between the standard Lamb design of the RAOs and the slightly more unusual design of the NC-80X/81X, which also used 1560 kHz as an IF frequency.

Mechanically, the design differs only in the calibration of the direct-reading dial.

The Coast Guard Versions

The R-115:

The Coast Guard R-115 used the same basic chassis and mechanical layout as the NC-200 but instead had only six bands, covering 200-400 kHz, and 490 kHz to 18 MHz. Lack of the amateur bandspread and crystal filter, which were in the NC-200, along with a completely different tube lineup, makes these easy to identify even without the Coast Guard data plates.

The R-115 was an ac-dc radio and contained an unusual tube lineup to facilitate this feature. With four 117N7s, it is quite different from its NC-200 cousin.

The R-116: (see detailed listing section) This prototype probably never reached production.

Figure 21. *The Type R-115 receiver, made for the U.S. Coast Guard.*
The James Millen Company DFP-201 and DFP-501

James Millen believed very strongly in the inherent advantages of his coil-catacomb design, and during the early 1940s he apparently kept several new catacomb-based designs on the back burner until after World War II.

In May, 1947 he announced the soon-to-be-available DFP-210 and DFP-501 radios. Documentation that the 201 was a coil-catacomb based-design is clear. Whether the 501 also used the coil-catacomb design is less clear. Very little information about these radios is available.

The 501 was a cost-no-object tour-de-force in radio design. It appears that only one prototype was ever completed. The 201, a reduced cost version of the 501, never reached production either. Reportedly, even the 201 prototype cost over $2,100 each to build in 1948 dollars!

Both the 201 and 501 were quickly withdrawn from the Millen catalogs, and none that I know of were ever shipped to end-users. I know of only one of each in existence.

Millen eventually gave up on the coil-catacomb design, as did National, perhaps because the market was moving to smaller, less-expensive radios. The unique coil-catacomb design was no longer cost effective in an evolving and changing market.

The Low-Cost Versions: NC-80X and NC-81X.

From QST, August, 1937...

This is an inexpensive receiver having exceptional operating characteristics. Ten tubes are used in a high-gain superheterodyne circuit as follows: 1st detector, 6L7; HF oscillator electron coupled, 6J5; three IF stages, 6K7s; linear 2nd detector, 6C5; amplified and delayed AVC, 6B8; panel-controlled beat-frequency oscillator, 6J7; beam-power output, 25L6G; and rectifier, 25Z5. The IF amplifier is of entirely new design, operating at a frequency of 1560 kc, and providing a high order of image suppression, better, in fact, than that obtainable in many receivers having elaborate preselectors. The crystal filter (2nd IF stage) is truly remarkable in its performance, since selectivity is continuously variable between 400 cycles for single signal CW, and 5 kc for high-quality broadcast. The range of the phasing circuit (heterodyne elimination) has been similarly extended. With such unusual characteristics, the crystal filter remains in the circuit at all times, simplifying tuning considerably. With the development of the 25L6G beam-power tube having an undistorted output of two watts, it has become possible to design a high-performance communication receiver operating with full efficiency on either ac or dc, 115 volts.
The tuning system, likewise entirely new, employs a multiple-scale dial of the full-vision type, accurately calibrated in megacycles. Several unusual features are incorporated, such as the mirror for overcoming parallax, the auxiliary linear scale (at the bottom), and the adjustable-frequency markers, by means of particular stations, or frequencies, such as band limits, may be "logged" on the dial itself. Two veneer-reduction ratios are available, 16 and 80 to 1, with a separate knob for each.

Automatic plug-in coils are used, controlled by a knob on the front panel, as in the NC-100. This arrangement has proven itself to be thoroughly reliable and efficient. The frequency coverage is continuous except for a small gap at 1560 kc, from 550 kc to 30 Mc in four ranges.

The NC-81X is a special amateur model covering the following bands only: 1.7 - 2.0 Mc, 3.5 - 4.0 Mc, 7.0 - 7.3 Mc, 14.0 - 14.4 Mc, and 28 - 30 Mc. The dial is calibrated in megacycles.

Only one month later (9/37) in his now famous monthly QST column, James Millen had this to say about the new NC-80X/81X radios:

"... Designed by Dana Bacon and his staff..."

"... Most amateurs do not need to be told that when a communication receiver is to be sold for as low a price as the NC-80X it is necessary to make compromises..."

Thus the low-cost versions of the coil-catacomb line were born. Economies in the NC-80X/81X included removal of the preselector circuits on the grounds that a good one would cost too much, and a cheap one wasn't
worth owning. Provision to control image rejection and provide usable signal-to-noise ratio fell onto the newly designed crystal-filter circuit. By using a 1560 kHz IF frequency, the image frequency is 3120 kHz removed from the desired signal. It was enough that image rejection remained adequate. The new crystal-filter design promised great things, according to Jim Millen:

"... By operating with optimum selectivity, the noise can be reduced sufficiently to make the signal-to-noise ratio fairly good (CW-noise equivalent approximately 0.3 uV)...."

Jim goes on by making a silk purse out of a sow’s ear concerning the ac-dc power supply of the NC-80X. He praises the cool running and good power regulation of such a design, then points out that the new beam-power amplifier tube give two watts of audio, which he calls “ample.”

Jim winds up his monthly column by saying: "... Of course the schemes described above are mostly only devices to make it possible to build a good receiver at a low price..."

James Millen revisited the NC-80X/81X radios in his column of December, 1937. He also touched on National component-manufacturing processes and how components not made in-house are specified and purchased from other vendors:

"... When production sets came through it became apparent that these condensers would not do. The ganging was not good enough and backlash was perceptible when using the high selectivity of the crystal on bandspread amateur bands..."

National addressed the problem by refitting PW condensers into the NC-81X amateur-bandspread version:

"... We found that by careful refitting these were satisfactory for the NC-80X (which has general coverage ranges) but not the NC-81X (which has extreme bandspread on the amateur bands.)..."

"... This refitting brought the cost up as high as a PW condenser, so what the heck..."

"... receivers are so late. NC-81X receivers with PW condensers will be delivered about the same time this page is published..."

He goes on to describe how they are currently filling NC-80X orders with refitted condensers, and how later production NC-80X receivers will also use PW-style condensers exclusively.

(Author’s note: My NC-80X has one of these “bought” condensers. I’ve never seen an NC-80X with a National PW condenser in it, and I speculate that very few, perhaps none, were ever made.)
The RBL Series (NC-100A look-alike):

The RBL series of VLF-LF Communications Receivers get a brief mention here because they strongly resemble a National NC-100A. They are often mistaken for the NC-100A, because of the large direct-reading dial, band-change knob in the same location as the NC-100A, etc. Perhaps the easiest way to spot an RBL is the low-frequency dial calibration, coupled with the existence of a regeneration control on the front panel.

Built with the same basic front panel and chassis as the NC-100A, internally they are very different. The RBL series are non-superheterodyne systems with two stages of tuned-radio-frequency (TRF) amplifiers, followed by a regenerative-detector circuit. Two stages of audio, with a limiter in between, finish the basic signal path. Typical frequency coverage is from 10 or 15 kHz to 600 kHz in five bands.

The National NC-1-39 & NC-1-39S:

This is a pair of odd radios apparently designed for special-purpose military-related uses. (See detailed alphabetical listing)
During the production years of the NC-100s, NC-101Xs and NC-100As National introduced a new series-noise-limiter circuit to many of its models. This change was documented in a brief four-page addendum supplied with the owner’s manual.

A 6C8G and a 6F8G replaced the 6C5 second detector and the 6J7 AVC tubes previously employed. The 6C8G comprises an infinite-impedance diode second detector and the new series-valve noise limiter, while the 6F8G is used for AVC and a new first audio stage. The circuit was described in some detail in the October, 1939 issue of *QST*.

The really interesting thing about this noise limiter is that the design change was made in mid-production for many of the early Nationals, without a model number change. The collector will run across later radios with the change and earlier radios without it.

Alphabetical Listing Of All Known National “Coil-Catacomb” Radios And Variants

For explanations of the references following each model refer to the bibliography on page 232.

Model designations are in alphabetical order.

AN/GRR-3 (M3, p. 95).

GRR-3 (M4 p. 110). World War II years? NC-100ASC, according to Moore.

BC-903-A (M3, p. 95)

WW II vintage. Range 0.54-30 MHz. No crystal filter. Navy version of NC-100A, according to Moore. BC-903-A is perhaps an Army Signal Corps designation.

NAO (AWA)

A very odd radio, that perhaps never went beyond the prototype stage. (?!) Appears to be another NC-100A variant with the extra RF preselector stage on the rear (see RAO series.) The front panel has a direct-reading “A”-type dial and a catacomb bandswitching knob, small rack handles, and front-mounted fuse holders. It does not appear to have a crystal filter.

Shown in National photographs as a rack-mount system, it is complete with a dual dynamotor rack-mount power supply. It appears to have navy-gray paint instead of the classic black-wrinkle finish. Post war? No other information is available.
Figure 24. The NAO receiver. It is configured for both ac and dc power sources. It also has a separate RF preselector on the back.

Figure 25, 25a. Battery-source power pack for both the NAO and NBL receivers. The meter is 10 Vdc full scale.
NBL (AWA)

Another very odd radio. Appears almost identical to the NAO, except for an added ¼” phone jack, labeled “XTAL,” and another extra control labeled “OSC TEST.” Appears to be another NC-100A variant with the extra RF-preselector stage on the rear (see the RAO series.) The front panel has a direct-reading “A”-type dial and a catacomb bandswitching knob, small rack handles, front-mounted fuse holders. It does not appear to have a crystal filter. It is shown in National photographs as a rack-mount system, complete with a dual-dynamotor rack-mount power supply. It appears to have a Navy gray paint finish instead of the classic black-wrinkle. Perhaps another post-war prototype? No other information available.

NC-80X (M3 p. 88, M4 p. 101)

1937-38. Four bands, 0.55 to 30 MHz.
1560 kHz IF, crystal filter, balanced and unbalanced antenna inputs, ac-dc power. A slide-rule dial, low-cost catacomb radio.
Tube lineup: 6L7 mixer, 6J7 HFO, 6K7 1st, 2nd, and 3rd IFs, 6C5 detector, 6B8 AVC, 6J7 BFO, 25L6 audio output, 25Z5 rectifier.

NC-80XB (M4 p. 101)

Battery version of NC-80X, 6V6 AF output, needs 135V B+ and 6V heater power.

NC-81X (M3 p. 88, M4 p. 102)

1937-39
Amateur-band-only model of NC-80X.
Five bands; 10, 20, 40, 80, 160 meters.

NC-81XB (M4 p. 102)

Battery model of the NC-81X.

The radio that started it all.

NC-100 (M3 p. 88, M4 p. 102, Man, Riders, NC1937, others)

1936-1938, five bands, 540-30,000 kHz
455 kHz IF (M3, M4), 456 kHz IF (Riders 8),
No crystal filter, PW-dial system.
Tuning-eye tube version.

This and the NC-100X are the so-called “Art Deco” design Nationals. A horizontal bright red strip, and silver and black vertical stripes set these apart from all the other coil-catacomb models.

203
Figure 26. This is the NC-100 ASC model. The panel label reads simply NC-100 A.

Figure 27. Top inside view of the NC-100 ASC receiver.
These designs are noted for easy access for servicing. What appears to be a fuse next to the transformer is actually a piece of brass rod, to select the proper input voltage.

Tube line up: (from manual, agrees with M3, M4, & Riders)*
6K7 RF amp, 6J7 mixer, 6K7 HFO, 6K7 1st and 2nd IFs, 6C5 detector, 6J7 AVC, 6J7 BFO, 6E5 tuning eye, 6F6(2) (push pull) audio output, 80 rectifier. *See Noise-Limiter Note

References include:
1935 National catalog (#250) p. 17, text block describing new NC-100 radio in preparation. (Possible first-ever reference in print to the NC 100.)
NC-100 Battery (M3 p. 88, M4 p. 102, Man)*1936-38, battery version of the standard NC-100
*See Noise-Limiter Note

NC-100A (M3 p. 88, M4 p. 102, Man) 1938-45
The "A" variant. A new, direct-readout tuning dial replaces the PW type. Five bands, 0.54—30 MHz, 455 kHz IF, S meter.
Tube lineup: 6K7 RF amplifier, 6J7 detector, 6J7 HF oscillator, 6K71st and 2nd IFs, 6C8 2nd detector/limiter, 6F8 AVC/1st audio, 6J7 BFO, 6F6G(2) push-pull audio, 80 rectifier.
(Note: The NC-100A and XA were also available in two different battery-powered versions; the first and more common required external B+ and filament power. The second, unusual version contained an internal vibrator-based power supply and required only 6 V dc to be provided.)

NC-100A special (M3 p. 88, M4 p. 102, PC)
NC-100A with LF band, 200-400 kHz (sometimes incorrectly called the NC-100ALF.)

NC-100ASC (M3 p. 88, M4 p. 102)
Moore's 4th says see GRR-3. (AN/GRR-3)

NC-100ASD (M3 p. 88-89, M4 p. 103, Man)
200-400 kHz and 1.3 MHz to 30 MHz, five bands, S meter, 456 kHz IF
   Band 1: 200-400 kHz
   Band 2: 1,300-2,800 kHz
   Band 3: 2,800-6,400 kHz
   Band 4: 6,400-14,000 kHz
   Band 5: 14,000-30,000 kHz
115V 60 or 25-Hz ac power supply.
Binding-post antenna connectors. Built to Army Signal Corps standards, this had a push-pull S-meter on-off switch instead of the more common toggle.

206
Tube line up: (from manual, agrees with M3 and M4)
6K7 RF amp, 6J7 first detector, 6J7 HF oscillator, 6K7 1st and 2nd IFs, 6F8G 1st audio + AVC, 6C8G 2nd detector + 2nd audio, 6J7 BFO, 6V6G audio output, 5Z3 rectifier.

NC-100S (M3 p. 89, M4 p. 103)*
NC-100 with special 12” speaker.
*See Noise-Limiter Note

NC-100X (M3 p. 89, M4 p. 103)*
NC-100 with crystal filter. This is the other National “Art Deco” design coil-catacomb radio. It was also available with a 200 – 400 kHz low-frequency band. This is sometimes incorrectly called the NC-100XL or XLF.
*See Noise-Limiter Note

NC-100X battery (M3 p. 89, M4 p. 103)*
NC-100 battery-powered model with crystal filter.
*See Noise-Limiter Note

NC-100XA (M3 p. 89, M4 p. 103)
An NC-100A with crystal filter. (See Fig. 17)

NC-100XAL special (M3 p. 89, M4 p. 103)
Has a crystal filter, a special 200-400 kHz LF band, and binding-post antenna terminals.

NC-100XS (M3 p. 89, M4 p. 103)*
The NC-100X with 12” speaker.
*See Noise-Limiter Note

NC-100XAM (M3 p. 89, M4 p. 103)

NC-101X (M3 p. 89, M4 p. 104), 1937-39. An amateur-band only version of the NC-100, PW dial, tuning eye, crystal filter, 455 kHz IF. Five bands; 160, 80, 40, 20, 10 meters.
The tube line up is identical to that of the NC-100, above. The earliest reference to this radio I have found is an ad in Feb. 1937 QST magazine. I also have a photocopy of a letter from James Millen to Bill Orr briefly discussing this unit.

NC-101X variation (M3 p. 90, M4 p. 104)*
S meter replaces the “eye” tube.
Push-pull S-meter switch.
*See Noise-Limiter Note
NC-101X battery (M3 p. 90, M4 p. 104). The battery version of NC-101X. Needs 180V B+ @ 35 ma and 6V heater power. The tube line up is identical to that of the ac version, with the exception that the audio output is a single 6F6 to conserve power.

NC-101XA (M3 p. 90, M4 p. 104). 1939-41. The amateur band version of NC-100A. S meter, noise limiter, crystal filter, 455 kHz IF. Five bands; 160, 80, 40, 20, 10 meters. The tube line-up is the same as the NC-101X, above, with the exception that the 6C5 2nd detector is replaced with a 6C8G combined 2nd detector/noise limiter.

NC-120 (M3 p. 90, PC, M4 p. 105, AWA) Similar to the NC-100A with an added RF stage bolted/welded to rear of cabinet, with a separate coil catacomb and variable tuning capacitor ganged to the main controls.

S meter, S-meter switch, crystal filter, 455 kHz Panadaptor output (SO-239 type.) Some have binding-post type antenna connectors and some have a coax antenna-input connector.

I have conflicting information concerning the NC-120. An original National photograph (thanks to Alan Douglas) of this radio is also marked “RA0-2”. I know of at least one NC-120 with the contract data plate still attached that says it is part of radio type CAN-46187. Yet this radio continues to be a minor mystery. Virtually identical to the RAO-3/4 and RAO-6, it is clearly a member of the family, yet my copy of the RAO 3&4 manual states that the manual is unsuitable for use with the RAO-2 due to significant differences between the radios. Mine also has a panadaptor output, which is shown in only SOME of the National NC-120/RAO-2 rear-view photographs. Antenna connections are another problem; mine has standard National type binding posts, yet National Company photographs show an unusual coax connector as correct. My antenna-binding posts are clearly unmodified.

<table>
<thead>
<tr>
<th>Five bands, 540-30,000 kHz</th>
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<tbody>
<tr>
<td>Band A 14-30 MHz</td>
</tr>
<tr>
<td>Band B 6.4-14 MHz</td>
</tr>
<tr>
<td>Band C 2.8-6.4 MHz</td>
</tr>
<tr>
<td>Band D 1.3-2.8 MHz</td>
</tr>
<tr>
<td>Band E 0.54-1.3 MHz</td>
</tr>
</tbody>
</table>

Tube data from my radio: 6K7 1st RF amplifier, 6K7 2nd RF amplifier, 6J7 1st detector, 6K7s 1st and 2nd IF amplifiers, 6F8G 1st audio and AVC, 6K6GT 2nd audio, 6J5 HF oscillator, 6J7 BFO, 5Z3 rectifier.
NC-127 (M3 p. 91 & 123, M4 p. 105)
World War II vintage. (Moore's book reports four bands (I believe it should be five) 0.54-30 MHz, 455 kHz IF, crystal filter. Similar to the NC-100XA. Has rack-type handles and front-panel captive-style rack-retaining screws.
Tube line up, from Moore’s 3rd, is similar to the NC-120, above, with the exception that the audio tube is listed as a 6V6. Note that both of these receivers have two RF stages.

NC-127D (M3 p. 91 & 123, M4 p. 105)
Used in an experimental triple-diversity system.
Only one system (three receivers) believed to have been made. Added two-position “DIVERSITY” control and a “DIVERSITY IF GAIN” control.

NC-1-39 (M4 p. 105)
Five bands, 0.54-30 MHz, crystal filter.
Moore reports this is another modified NC-100XA with two headphone jacks. Designed for headphones use only; no audio-power amplifier.
Tube line up from Moore’s 4th:
6K7 RF amplifier, 6J7 1st detector/mixer, 6J7 HFO, (2) 6K7 IF amps., 6C5 2nd detector, 6J7 AVC, 6J7 BFO, 80 rectifier

NC-1-39S (M4 p. 105)
Five bands, 200-400 kHz, 0.495-1.060 & 1.3-14.4 MHz
Same as NC-1-39 except for band coverage.
Radio is intended for VLF and direction-finding (DF) use.

NC-156 (MAN)
Navy NC-100XA variation, with 1560 KHz IF system, and unusual tuning ranges. Unlike the later NC-156-1 and -2, the standard NC-156 does not have the extra RF stage. Also known as Type CNA-46144, and the RBH, the manual I have lists the General Electric Supply Corp. as the primary contractor (see RBH.)
Ten (10) tubes, S meter, 1560 KHz crystal filter.
Five bands: 300-600 kHz, 600 kHz - 1.2 MHz, 1.7-3.9 MHz, 3.6-8.2 MHz, 8-17 MHz.
Tube line up: 6K7 RF amp, 6J7 first detector, 6J5 HFO, 6K7s 1st and 2nd IFs, 6F8G 1st audio + AVC, 6C8G 2nd detector + limiter, 6J7 BFO, 6V6G audio output, 5Z3 rectifier.
Figure 30, 30a. Bottom view of the NC-200 receiver. Typical of all these radios, all sub-chassis parts are readily accessible.

NC-156-1 & NC-156-2 (M3 p. 91, M4 p. 106, PC, MAN, AWA)
Navy NC-100XA with two RF stages and a 1560 KHz IF chain. Eleven tubes, S meter, 1560 KHz crystal filter. Only known difference between the -1 and -2 versions is removal of a “dummy” plug (replaced with a blank plate) on the rear of the radio.
Five bands: 300-600 kHz, 600 kHz - 1.2 MHz, 1.7-3.9 MHz, 3.6-8.2 MHz, 8-17 MHz. (See RBH series)
Tube data from my NC-156-1 radio: (2) 6K7 1st and 2nd RF Amplifiers, 6J7 1st Detector, (2) 6K7 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT 2nd audio, 6J5 HFO, 6J7 BFO, 5Z3 rectifier.

NC-200 (M3 p. 92, M4 p. 107, Man, Riders 14, AWA), 1940-43
Ten bands 490-30,000 kHz, 6 general coverage, 4 amateur bandspread on 80-40-20-10 meters. Crystal filter, 12 tubes, S meter. Ten ranges, calibrated frequency dial. This is the first of the coil-catacomb radios to have both “general coverage” and “bandspread” amateur bands in the same radio. The main tuning control has a push-pull function that allows selection of either of the six general coverage or four ham bands as well
as tuning the desired frequency range. This radio has the louvered sides, also seen on the later NC-2-40-series radios. The cast coil-catacomb on these and later models, which have both general-coverage and amateur-bandspread ranges, have a far more complex internal construction than the original designs.

Tube lineup from manual: 6SK7 RF amplifier, 6K8 1st detector, 6J5 HFO, 6K7 1st IF amplifier, 6SK7 2nd IF amplifier, 6C8 2nd detector/limiter, 6SJ7 AVC, 6SJ7 BFO, 6F8 1st audio and phase inverter, 6V6(2) push-pull audio output, 5Y3G rectifier.

NC-200RG (M3 p. 93, M4 p. 107)
Rack model of above

NC-200TG (M3 p. 93, M4 p. 107)
Table model of above, (may be same radio: nomenclature issue.)

NC-200TGM (M4 p. 107)

NC-200TG without amateur bandspread.

NC-2-40 (M3 p. 93, M4 p. 108), 1943-44. (Successor to NC-200 according to Moore.)
Six bands, 0.49-30 MHz, 455 kHz IF, crystal filter, 13 tubes, S meter.
Tube lineup: 6SK7 RF Amplifier, 6K8 Mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6C8 Detector/NL, 6SJ7 AVC, 6SJ7 BFO, 6J5 1st Audio, 6F8 Phase Inverter, 6V6(2) push-pull Audio output, 80 Rectifier.

NC-2-40C (M3 p. 93, M4 p. 108, SRPP p. 234, Riders 15), 1945-46 (M3, M4) 1946-47 (SRPP)
115-230 Vac, 455 KHz IF, crystal filter, S meter.
Six bands, 490-30,000 kHz. Tubes: 6SK7 RF amplifier, 6K8 mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6SL7 detector/NL, 6SJ7 AVC, 6SJ7 BFO, 6SN7 1st audio/phase inverter, 6V6(2) push-pull audio output, 5Y3GT rectifier.

NC-2-40CR (SRPP p. 234) Rack version of NC-2-40C.

NC-2-40CS (M3 p. 93, M4 p. 108, SRPP p. 234, Riders 15)
Same as NC-2-40C except has LF band 200-400 kHz and 1000-30,000 kHz coverage.

NC-2-40CSR (SRPP p. 234)
Rack version of NC-2-40CS.
Figure 31. A representative model of the NC-2-40 series with matching speaker. This is a NC-2-40 C.

Figure 32. Another NC-2-40-C, for rack mounting, with matching speaker.
Figure 33. Top view of a NC-240 CS.

Figure 34, 34a. Below the chassis of the NC-2-40 D. The inset shows one of the RF transformers.
10 bands, 490-30,000 kHz, 6 GC + 4 amateur bandspread; 10, 20, 40, 80 meters.
455 kHz IF, crystal filter, S meter. Tubes: 6SK7 RF amplifier, 6K8 mixer, 6J5 HFO, 6K7 1st IF, 6SK7 2nd IF, 6SL7 detector/NL, 6V6 AVC, 6SJ7 BFO, 6SN7 1st audio/phase inverter, 6V6(2) push-pull audio output, 5Y3GT rectifier.

NC-2-40DR (M3 p. 93, M4 p. 108)
Rack model NC-2-40D.

NC-2-40DT (M3 p. 93, M4 p. 108)
Table model of the above.

NC-2-40S (M3 p. 93, M4 p. 108, Man)
Has odd coverage of 0.2-18 MHz, but otherwise same as NC-2-40 (according to Moore.) Six bands: 200-400 kHz, 490-1,060 kHz, 1,000-2,400 kHz, 2,200-5,000 kHz, 4,500-10,000 kHz, and 9,000-18,000 kHz.
External type 2-42 power unit required. Cable with 7-prong connector supplied. 115/230 Vac. Binding-post antenna terminals, S meter, crystal filter.
Tubes (from my manual copy): 6SK7 RF amplifier, 6K8 1st detector, 6J5 HFO, 6K7 1st IF amplifier, 6SK7 2nd IF amplifier, 6C8 2nd detector/limiter, 6SJ7 BFO, 6SJ7 AVC, 6F8 1st audio/phase inverter, 6V6(2) audio output, 6J5 headphone amplifier, 80 rectifier (in power supply.)
Note: The manual copy I have states: “Made for Pan American Airways System, Chrysler Building, NYC” on the cover.

NRCL (M3 p. 95, M4 p. 110) 1944-45 NC-100 variant for dual-diversity system, part of NCRM system.

NCRM (M3 p. 95) 1944-45 NC-100-based dual-diversity system. Probably experimental. M3 is the only reference so far.

R-115 (M3 p. 95 & 123, M4 p. 111, AWA)
World War II vintage. Made for US Coast Guard. Ac-dc receiver.
Six bands, 200-400 KHz and 490KHz to 18MHz. Similar to NC-200, but without amateur bandspread or crystal filter.
Figure 35. The unusual ac-dc R-115 sliding-coil receiver made for the Coast Guard.

Figure 36. The R-116 receiver designed for the Coast Guard, with separate power pack, in a sliding rack mount.
Note: R-115 sounds like a JAN (Joint Army-Navy) designation, which would probably have a AN/SRC-*** (for surface ship) or AN/GRC-*** “system” designation as well.

Tube line up (from Moore’s): 4-117N7, 3-12SK7, 1-12K8, 1-12J5, 1-12SC7, 1-12C8, 1-12SR7, 1-12SJ7. (This must be a very odd set...)
Contract: TCG-23454 Order #: CG-80110? Date: 10DEC1940

R-116 (AWA)
NC-100A-based US Coast Guard Radio Receiver; may never have proceeded beyond prototype stage.
Mostly unknown, has crystal filter, BFO and AVC control, 300/600 ohm speaker terminals & binding post-type antenna terminals.
Contract: TCG-33675 Order #: CG-80265? Date: 15MAY1941

The RAO Receivers
RAO Notes: Moore’s 3rd reports RAO-1 through RAO-8 as identical radios. I have found that this is not the case. Each model has variations enough to justify separate listings. Some radios have S meters, some have aux. “Panadaptor” outputs. Several different “antenna” connectors were used, including binding posts, an odd oversized Motorola type plug and SO-239s? (I continue to wonder how original/correct the SO-239s are.) Minor differences in rear-panel layout of power, speaker, antenna, and battery connectors exist. I suspect that differences between manufactures exist even within the same series number. (At least in tube line up they do: i.e. 6F6, vs. 6V6, vs. 6K6 audio output.) Because the RAO series were built during World War II primarily for the Navy, small engineering changes may have been made from production run to production run just because of parts availability. Information that exactly matches many RAO series radios has proved difficult to locate. Several RAOs I have examined do not exactly agree with the Navy documents for that model. It appears that some units were built only by National, (RAO-2/6? ,) some only by Wells-Gardner, (RAO-4?) and some by both companies. I continue to research this issue. Where the National NC-120 fits into this puzzle remains unclear. I own one NC-120 and have seen several others. None exactly match the National photographs.

Moore’s 4th adds another variation: On p. 111 is an RAO without a suffix number/code.
(See RAO)

I have also located several references in National documentation to an RAO-9 radio. (see RAO-9)
This remains mostly a mystery set.
Figure 37. The model RA0-1 receiver. This is a very early version, starting life as an NC-100 XA (Fig. 17). Note the plug-in crystal unit. There is no added preselector stage on the -1 version.

Moore’s 3rd lists generic data for the RA0-1 through RA0-8 as follows: Crystal filter, added RF stage, 455 kHz IF, five bands, 540-30,000 kHz. Tubes: 6K7 1st RF, 6K7 2nd RF, 6J7 mixer, 6J5 HFO, 6K7 1st IF, 6K72nd IF, 6C8 detector / noise limiter, 6J7 BFO, 6F8 1st audio / AVC, 6V6 audio output, 5Z3 rectifier.

RAO (M4 p. 111) 1938
Five bands, 0.54-30 MHz coverage, 456 kHz IF, crystal filter. Moore (4th) lists the Navy designation as CNA-46072, with GE as the contractor. He also reports that this very early version does not have the added RF stage attached to the back.

RAO-1 (M3 p. 95, M4 p. 111)
World War II vintage, built for the U.S. Navy. Similar to the NC-100 XA, without the preselector added to the subsequent models. May have been built by Wells-Gardner as well as National, using National parts.
Figure 38. Model RAO-6 receiver in mounting rack. This is also designated an NC-120.

Figure 39. Top view of the RAO-2. The photo is dated October 14, 1942.

Figure 40. Top view of the RAO-7, dated Jan./Feb. 1944. Compare this with the RAO-2 in Fig. 39.
RAO-2 (M3 p. 95, M4 p. 111, AWA)
World War II vintage, built for US Navy, similar to the above. This is
the Navy version of the NC-120 radio.
(See NC-120) Part of CNA-46187 radio system.
High S/N known is #2112, date code: 11/20/1943

RAO-3 (M3 p. 95, M4 p. 111, partial Man)
World War II vintage (Navy type CWQ-46187-A), built for US Navy,
similar to the above.
Built by National as well as Wells-Gardner, using National parts.
115Vac, 60 Hz. Five bands, 0.54-30 MHz, has odd antenna connector,
S meter, with switch, crystal filter, no Panadapter output.
Known contract(s): NXss-21446 High S/N known: #853, date 11/18/1943.
Tubes: (manual) (2) 6K7s 1st and 2nd RF amplifiers, 6J7 1st detector, (2) 6K7s 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT 2nd audio (output), 6J5 HFO, 6J7 BFO, 5Z3 rectifier.

RAO-4 (M3 p. 95, M4 p. 111, partial man, PC)
World War II vintage. (Navy type CWQ-46187-B) Built for US Navy, similar to the above, by National as well as Wells-Gardner, using National parts. 115 or 230V 60 Hz ac, and except for dual-input main-power transformer, the same as RAO-3. Range 540 kHz - 30 MHz, five bands, odd antenna connector. S meter, S-meter switch, crystal filter, no Panadapter output.

Tubes: (manual in my files): (2) 6K7s 1st and 2nd RF amplifiers, 6J7 1st detector, (2) 6K7s 1st and 2nd IF amplifiers, 6C8G 2nd detector & limiter, 6F8G 1st audio & AVC, 6K6GT 2nd audio, 6J5 HFO, 6J7 BFO, 5Z3 rectifier.
(Note: My Wells-Gardner RAO-4 has a 6V6 audio output, not the 6K6 the Navy (National) manual specifies. "6V6" is printed (inked) next to the tube socket.)
Known contract(s): NXss-21446. High S/N unknown. (See RAO-3)

RAO-5 (M3 p. 95, M4 p. 111)
World War II vintage. Built for US Navy, physical description as above. May have been built by other contractors (Wells-Gardner, etc.) as well as National, using National parts.
Moore reports (4th) that the USN code for this radio was: CWQ-46229

RAO-6 (M3 p. 95, M4 p. 111, Man, Pvt.)
World War II vintage, Navy type # CNA-46187-D, Part of Navy CNA-46233 Receiver System. Similar to above. May have been built by Wells-Gardner as well as National, using National parts. Five bands, 540-30,000 kHz, eleven tubes, crystal filter, S meter, 455 kHz IF, has aux. Panadapter output with SO-239 connector. The odd oversized antenna connector is correct for the Type 6.
Known contract data:
NXsr-38306 high S/N ? Date: 22SEP1943 (from my manual copy)
NXsr-38306 high S/N 648 Date 31JAN1945 (Pvt. communication)
NXsr-38306 high S/N 653 Date 15JUN1944 (Pvt. communication)
Tubes: Identical to RAO-6 above.
RAO-7 (M3 p. 95, M4 p. 111, Man, Pvt., AWA)
World War II vintage, Navy type # CNA-46233
Built for US Navy, similar to above. Has SO-239-type Panadaptor output on back.
NC-127 look-alike, with heavy rack-type capture screws around face.
(May have been built by Wells-Gardner as well as National. Still an open question.)
Coverage 0.54 to 30 MHz in five bands. Crystal filter. 455 kHz IF.
Known contracts:
NXsr-55614  high S/N 1587 date: 31MAY1945 (Navy Bureau of Ships)
NXsr-38306  high S/N 444  date: ?
Part of Navy CNA-46233 Receiver System.
In the case of the RAO-7 some interesting information was found in a copy of the “Preliminary Instruction Book, Contract NXsr-55614, 13FEB1945.” The document states that: “1073 “receivers” were contracted for, along with 1073 “Spare Parts Sets,” 107 Stock Spare Parts Sets,” 4146 “Preliminary Instruction Books,” (this data is from one of them) 4646 “Final Instruction Books,” and 107 unspecified “Additional Spare Parts.” (Pvt. communication)
Tubes: Identical to the RAO-6, above.

RAO-8 (M3 p. 95, M4 p. 111)
World War II vintage, Built for US Navy. Similar to above. May have built by Wells-Gardner as well as National, using National parts.

RAO-9 (Brief mention in my National RAO-7 manual, AWA)
Part of Navy System: CNA-46283. Has both small rack-mount handles and capture screws on the front panel, like the NC-127. Crystal filter, Panadaptor output, odd coaxial-type antenna connector. Another NC-100A variant with the extra RF preselector built on the back. No other data available.

RBH Series (M3 p. 96, M4 p. 111, MAN, Pvt.)
(Note: Moore’s 3rd & 4th do not differentiate between the three versions.)
Navy NC-100XA-type variations, some with two RF stages, the extra stage bolted to rear like most RAO series. Unusual 1560 kHz IF. (See NC-156, NC-156-1, NC-156-2)
Known contracts:
*RBH Contract # 87668, major part of CNA-46144; contractor was the General Electric Supply Company.
Figure 43. The RBH-1 set in its mounting rack. Photo dated 2/22/43.

Figure 44. Top view of the RBH-1. Photo dated 2/22/43.
Figure 45. The RBL-6. This is a sample version for evaluation. Not a coil-catacomb receiver, although it resembles one.

General Electric Supply Company.
*RBH-1 Contract Number NXs- 738, major part of CNA-46188 system, high serial number unknown; contract date was April 30, 1942
*RBH-2 Contract Number NXss-19881, major part of CNA-46188 system, high S/N known: #1269; contract date was January 2, 1943
*RBH-3 Contract Number NXsr-33381, major part of CNA-46188 system, high serial number unknown; contract date was June 30, 1943

RBL-1 through 5 (PC, Man, AWA)
Built on the NC-100A chassis, this VLF-LF receiver is only a NC-100A look-alike on the outside.
Under the skin, it is a completely separate design based on TRF tuning and regenerative detection.
Range of 10-600 KHz. Made by National and Wells-Gardner using National parts.
World War II years. (A very interesting, and fun-to-use radio. Without a coil catacomb, it doesn’t really belong to the NC-100 family. Often mistaken for a NC-100A.)

RC-120 (AWA)
An NC-100A variation built for the US Coast Guard. Range of 2-18 MHz in three bands.
This one has a tuning eye instead of the normal — for the 100A series — S meter. In addition, does not appear to have a crystal filter installed.
Contract TCG-33991? 24SEP1941 (Appears to be a very early 100A variant.)
“Airways Ground Receiver” (AGR) series:  
Note: All AGR-series radios were rack-mount versions, designed for the standard 19”-rack environment. They were sometimes supplied with an optional enclosure for desk or tabletop use.

**RCD (PC)**

Early NC-100X CAA variant. Has crystal filter, and 6E5 tuning-eye tube.  
Push-pull audio output. With 200 – 400 kHz low band.  
I believe this was the first of the CAA AGR series. This radio seems to be a standard early NC-100 (w/ tuning eye). Equipped with the low-frequency first band option, (200 – 400 KC) in a 19” rack-mount configuration.

Tubes: 6K7 RF amp, 6J7 mixer, 6K7 HFO, 6K7 1st and 2nd IFs, 6C5 detector, 6J7 AVC, 6J7 BFO, 6E5 tuning eye, 6F6(2) audio out (push pull), 80 rectifier.  
Known contracts:  
Built by National; information from data plate on radio.

**RCE (M3 p. 96 & 123, M4 p. 112, AWA)** “Airways Ground Receiver” *  
Modified NC-100 for airport control tower use. From about 1937-38.  
Five bands, 200 - 400 kHz, 1.3-30 MHz. 457 kHz IF, no crystal filter, binding post-type antenna terminals.  
Tube lineup from Moore’s 4th: 6K7 1st RF, 6J7 1st detector/mixer, 6J7 HFO, (2)6K7 1st and 2nd IFs, 6C5 2nd detector, 6J7 AVC, 6J7 BFO, 6J7 INS control, 6C5 1st audio, 6V6 audio output, 80 rectifier.
BFO, 6J7 INS control, 6C5 1st audio, 6V6 audio output, 80 rectifier.

Known Contracts:

*Contract (# unknown) Order # 38-2833. High S/N #187 01OCT1937

Built by National, modified by Westinghouse Electric and Manufacturing Co.

*Contract (# unknown) Order # 38-2832 High S/N #78

Date unknown

Built by National, modified by Bendix Radio.

*At least one prototype unit of the RCE was manufactured by National with crystal control. National photographs #938 & 968, 969, 970 & 971.) Labeled as the model RCE-X.

**RCF (Man. Pvt.) “Airways Ground Receiver”**

“Interchannel Noise Suppression” radio. 457 kHz IF; does not have variable bandwidth IF transformers.

Does not have crystal frequency control option.

(Interestingly, the picture in the RCF manual of the radio shows a Bendix Radio Corp. data plate.)

Tube lineup from manual: 6K7 RF amp, 6J7 mixer, 6J7 HFO, (2)6K7s 1st and 2nd IF amplifiers, 6C5 detector, 6C5 1st audio/squelch, 6J7 BFO, 6J7 AVC, 6J7 I.N.S. amplifier, 6V6 audio output, 80 rectifier.

Known contracts:

Contract (# unknown) Order # 39-2748 High S/N #118

Date: 30JUN1939

Made by National, supplied by Federal Telegraph Co. Newark, NJ

**RCH (AWA photo)**

Five bands, 200 - 400 kHz, 1.3-30 MHz. Modified NC-100, PW dial, I.N.S. system.

Known contract(s):

Contract (# unknown). Order # 40-1760, high S/N unknown.

Date: 19OCT1939

Made by National, supplied by Bendix Radio Corp. Baltimore, MD

**RCK (M3 p. 96, M4 p. 112, RCP manual p. 5,AWA) “Airways Ground Receiver”**

Moore’s 3rd calls this a NC-100A, Moore’s 4th a NC-100. It is a modified NC-100 (not A) chassis with a PW dial. Mostly an unknown variant, mentioned briefly in the RCP manual. Some National Co. photographs exist of a type RCK-1. They show both C.O.N.S. and variable bandwidth IF, and a dual 120/240 V ac power supply. No crystal-control option.


Built by National for General Electric Supply Corp., Washington, D.C.
Figure 47. Receiver designated by National as RCK-N12-C, with
Russian language markings. Photo dated July, 1944. Note the unusual
frequency ranges.

*Contract, Cca-978 Order # unknown. high S/N unknown.
Built by National for Bendix Radio Corp.
*Contract (unknown) Order # 38-2833 high S/N 187 Date:
01OCT1937
Built by National, modified by Westinghouse Electric and Manufacturing
Co.
*Contract (unknown) Order # unknown. High S/N #235.
Date: 30JUN1939
Part of VF Radio Equipment No. 6736 (Pvt. Communication)

RCL (M3 p. 96 & 123, M4 p. 112, Man, AWA) "Airways Ground

Figure 48. Top view of the -N12-C. This set uses an external
power source."
Modified NC-100, Roughly World War II vintage. Five bands, 200 - 400 kHz, 1.3-30 MHz. 455 KHz IF with odd modified variable-coupling IF transformers.

The IF coupling can be changed from sharp to broad with a front-panel switch. This feature was later deleted when government contractors refurbished these radios. (See type RCP & RCQ.) Squelch circuit (CONS) added. Crystal oscillator-tuning option added.

Tube lineup from Moore’s 3rd & 4th: 6K7 RF amp, 6J7 mixer, 6J5 HFO, (2)6K7s 1st and 2nd IF amplifiers, 6C5 detector, 6F8 1st audio/squelch, 6J7 BFO, 6J7 AVC, 6J7 CONS amp, 6V6 audio output, 80 rectifier.

RCP (M3 p. 96, M4 p. 112, PC [2], Man, PVT) "Airways Ground Receiver"

Moore calls this a NC-100A on page 96 of his 3rd edition. This is incorrect; it is a NC-100 (no A) chassis with a PW dial. Modified NC-100, roughly World War II vintage. Range 200 - 400 kHz, 1.3-30 MHz. 455 KC IF with three odd modified variable coupling IF transformers. Squelch circuit (CONS) added. Crystal oscillator tuning option.

Known contracts:
CCA Contract # Cca-24653 Order 46-1467, high S/N #825, 30OCT1945, built by National, modified by Schuttig & Company, from an RCK or RCL. (See manual page 5)
Tube data from manual in my files: Virtually identical to that of the RCL and RCP above, except that the 6C5 detector has been replaced by a 6H6, serving as 2nd detector and noise limiter.

RCQ (Man. Pvt.) “Airways Ground Receiver”

A modified NC-100 Communications receiver, range 200 - 400 kHz, and 1.3-30 MHz. 455 kHz IF, with two odd modified variable coupling IF transformers, squelch circuit (CONS) added, crystal oscillator-tuning option.

Known contracts:
CCA, contract # CCA-26227 high S/N #404, dated 05FEB1948, made by National, modified by National Electric Machine Shops, Silver Springs, MD. From a type RCK or RCL. (See manual page 5)
I believe this was the last of the CAA contracts. An acquaintance has reported owning one of these with S/N B366. Unfortunately all the contract data plates are long gone from his radio. Could there have been more than one series?
RHZ (unknown variant, mentioned briefly on page 5 of RCQ manual, Pvt.)

Known contracts:
*CAA, contract # Cca-15856, high S/N #35, made by National, modified by Communications Equipment Corp., Pasadena, CA.
*CAA Contract # Cca-232876, high S/N #1048, made by National, modified by Communications Equipment Corp., Pasadena, CA.

For reference notes on detailed listing data, see the Bibliography section.

Notes on Speakers

Matching speaker information is often as hard to find as the matching speakers are themselves, so this is an incomplete listing.

Figure 49. Typical National rack-mount speaker with matching output transformer. This is an 8" PM Rola.

Figure 50. Another Rola speaker for use with a table-model National radio.
For the NC-100 and NC-101 series:
The DCS-8 (8”) and the DCS-10 (10”), both black with an embossed National Logo.

For the NC-200:
The NC-200-TSG, two-tone gray with chrome trim.

For the NC-2-40 series:
The NC-2-TSG, 10” PM speaker in two-tone gray with chrome trim and feet.
The NC-2 RS, 10” PM speaker on 10 1/2”gray wrinkle-finish rack panel.

A Note On Noise Limiters - Still More Variations

During the production years of NC-100s, NC-101Xs and NC-100As National introduced a new noise-limiter circuit to many of its models. This change was documented in a brief (four-page) addendum supplied with the owner’s manual.

A 6C8G and a 6F8G replaced the 6C5 second detector and the 6J7 AVC tubes previously employed. The 6C8G elements comprise an infinite impedance diode second detector and the new series-valve noise limiter while the 6F8G is used for AVC and a new first audio stage. The circuit was described in some detail in the October, 1939 issue of QST.

The really interesting thing about this noise-limiter is that the design change was made in mid-production for many of the early Nationals, without a model number change. The collector will run across later radios with the change and earlier radios without it.

Some Notes on the Coil Catacomb Assemblies

The cast coil-catacomb assemblies themselves are only superficially identical. There are a number of different variations in the casting. All have the cast-in “bosses” at the rear through which the main rail runs. Some have fiber-insert bushings in the bosses, and these are often in very poor shape. I have had good luck replacing these with small pieces of Teflon plastic tubing which I located at a local surplus store.

The drive teeth, which engage the drive gear, are located at the front of some castings and roughly in the middle of others. The drive mechanism, which controls catacomb position in the radio to select the band, was made in a number of variations. Some (NC-200, NC-2-40, etc.) engage only when the main-control knob is in the pulled-out position. Others, such as in the NC-100, NC-100A, are always engaged. Some NC-100As have a movable dial pointer connected to the band-select system in such a way that the pointer length
shows which band is selected, while others have a rotating ring around the knob to show the band in use.

The NC-200 & -2-40 series allow the selection of up to ten different frequency ranges or bands with a small moving-band indicator along the bottom of the direct-reading dial assembly. All direct-reading dial models are also equipped with an auxiliary-logging dial to improve the repeatability of the system.

The band-switching contacts on the upper side of the cast catacombs are designed to be self-wiping and to provide a positive connection and detent feel as the bands are changed.

The spring contacts that the coil-catacomb assembly engages are located directly beneath the main tuning capacitor in the radio, and are also designed to be self-wiping. Most are silver-plated, phosphor-bronze spring alloy. In most models, one set of contacts (the oscillator - Ed.) has a small piece of insulating material between the contacts located in such a way as to allow the contacts to act as a spring-loaded switch. This switch disconnects the screen voltage from the vacuum tubes when the coil catacomb is between bands, preventing extremely loud electrical noises from appearing at the speaker or in the headphones when the band is changed. It also prevents the vacuum tubes themselves from drawing excessive current if the radio is left between bands with the B+ voltage turned on for an extended period.

**Some Notes on Common Problems and Failures**

Probably the single most common failure in all the old National coil-catacomb receivers is the main power transformer. Almost half of the radios I know of have or have had at one time main transformer failures. The design of power transformers has not changed much in sixty years, but the materials used have. Wire varnishes have improved, sulfated paper has been replaced by poly-based plastics, and cloth-wire insulation has gone the way of the dinosaur. Asphalt pitch no longer “pots” components, and we seldom worry about component stress from high voltages in our new low-voltage world.

Transformers, filter capacitors, chokes and all the rest of the high-voltage (by today’s standards) power-supply components need to be treated with care. I strongly recommend the use of inrush current limiters to help preserve these radios. Placed in the 115-120V ac primary-power circuit, they will provide a nice “soft-start” effect that helps minimize the strain on sixty-year old impossible-to-replace components. These can easily be added in an invisible, reversible, manner under the chassis.

Wax-coated capacitors are another common failure. In fact, I’ve never seen a coil-catacomb National receiver without bad ones. If you wish to power-up the set, replace them all with modern metalized poly parts (get the type
rated for RF use) and your radio will perform much better. In fact, modern capacitors have expected lifetimes far longer than the owners!

Mica "postage-stamp" capacitors are usually still good, but watch out for the larger-value units that may appear to be mica, but are actually paper with a molded exterior. These often show up in decoupling circuits; they are very prone to leakage.

Fortunately none of the coil-catacomb Nationals used unusual hard-to-find vacuum tubes, and all of the RF tubes are still readily available from many sources. The rectifier and audio output tubes are only slightly more expensive and harder to find. The main tuning capacitors and PW dial assemblies are quite rugged, can be cleaned, and will give many more years of service unless they have been mechanically damaged. (Note, however, that the metal castings on some of these dials have distorted by being exposed to prolonged periods of dampness. They can be restored with careful work...refer to a back issue of the Old Timers Bulletin (Nov. 1995, Vol.36, No. 4) for details on the procedure. - Ed.)

Credits:

Many people contributed freely to my research. While I do not have the space to list each by name, I wish to extend a very special Thank You, in addition to individuals, to the "Boatanclors" Internet mailing list, for a long list of submissions, thoughts, comments, and critiques. Now thriving under the loving care of Jack Hill at Hyperlink (mail to: <boatanclors@sco.theporch.com>), "Boatanclors" is without a doubt the premier Internet information source for serious collectors, restorers and admirers of vintage vacuum-tube communications equipment. Contact Jack at Hyperlink; mail to: <listown@sco.theporch.com>, <listown@jackatak.theporch.com> for information on subscribing and dues.

I would like to extend a special thanks to William Fizette of the A.W.A. for providing both the forum and the encouragement required to complete this article. And also to Alan Douglas for encouraging me when this article was just a "I'll-write-it-someday" idea, and for making available the only still-existing official National Company Marketing Dept. photographs, many of which grace this article. Alan saved them from a dumpster years ago, and every National collector in the world owes him a debt of gratitude for his foresight.

(Note: We have volumes 9-13, 15, 17, 18, and 20. The others are missing and are presumed lost. However, if anyone knows of their whereabouts, please contact either the author or the editor. Ed.)

No work of this nature is ever truly finished, and new information comes to light constantly. Anyone who can add contract numbers, serial numbers, manual copies or any other information is invited to contact me.
Published works such as Ray Moore’s books, William Fizette’s columns in the AWA Journal, The Old Timer’s Bulletin, and Alan Douglas’s works in Antique Radio Classified and other venues have been extensively mined for information. I’ve tried to properly credit authors throughout this work, but undoubtedly have failed from time to time. All errors, omissions, mistakes, and mis-quote are mine alone.

The author has attempted to maintain some standards concerning use of electronic terms, which have changed over the years. Where quoting from manuals, magazine columns, etc. the original term has been retained. Thus “condensers” and “capacitors,” “1st detector” and “mixer,” may be used interchangeably. You will also see dual use of the terms kc. and kHz. Sentence syntax has changed somewhat over the years, but you may rest assured that where it has been badly mangled the fault is mine.

Significant portions of this work have been copied verbatim from much earlier National Company, Inc. and James Millen literature. In each case, the original author wrote something that I feel is of historical importance, and thus has been reproduced here.

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Bibliography & Notes

Major sources of information included:

AWA - Photographs from The National Company, Inc., provided to the author by Alan Douglas and William Fizette.


MAN - Original and photocopy manuals in my files.

MAG - Original and photocopies of magazine articles in my files. From CQ, QST, etc.

NA – original or photocopies of National Company, Inc. advertisements in my files.

From magazines, ARRL handbooks, etc.
NC - Original and photocopy National catalogs in my files.
NF - Original and photocopies of National advertising literature in my files.
PC - Radios in my personal collection.
PVT - Private communications with current owners, former National employees, knowledgeable fellow National collectors, etc.


RIDER XX - John Rider's "Perpetual Radio Trouble-Shooter" manuals.

Contract data: Contact numbers, Order numbers, dates, S/Ns, etc. are as reported by owners, from manual copies, and my personal radio collection. You are invited to help "fill in the blanks."

Photo captions by the editor.
Larry first became interested in short wave receivers when still very young, while spending a summer with an aunt and uncle on a WV farm. Seems the uncle had been a Navy radioman during World War II, and had an old black wrinkle-finish communications receiver in the workshop. Larry discovered the joy of listening to the powerful SW BC stations, and was "hooked." Later, remembering the magic of those nights, he studied electronics, acquiring along the way an AS in Computer Science and a BS in Electronics Engineering Technology.

In due course the old radio, an NC-120, became his and after some clean-up it still worked! He then discovered that being an SWL with the big old National is not the same as using a modern solid-state rig. It's at least ten times the fun! The "magic" is back; a dark room, glowing firebottles, and those voices from all over the world. He was hooked again, and has since acquired a whole shopping list of National catacomb and other receivers for his personal collection.

Early in the process of acquiring and repairing the coil-catacomb sets, he found that while volumes of information existed on the HRO, little could be found on the catacomb receivers. He started collecting information, and decided to assemble it into a somewhat coherent and hopefully correct presentation. This paper is the result - to date, he emphasizes.

Larry’s professional background includes work experience with Xerox, the FAA, GE, DOE National Laboratory, AT&T, and three years with GTI Telecom as Manager of Technology Development. He is currently owner and president of Wayward Enterprises, Inc., providing telecommunications project management services to the long-distance industry. In his spare time, he provides NOS (new old stock), used and reproduction parts to National collectors, and refurbishes older items of HP, Fluke and Tektronix test equipment. He resides with his wife, Pamela, in the Orlando, FL area.