The AWA Review

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Cover images: Front: Hallicrafters 5-T Sky Buddy with Boy, and without Boy. Back: Parts of the 5-T with Boy dial (Fig. 7 in article), and Hallicrafters 5-19 Sky Buddy.

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Foreword

In the year 2014 the AWA is recognizing contributions of the Hallicrafters Company. To mark the occasion, **Erich Bruesche** has provided us with the history of the Hallicrafters Sky Buddy series. Further, in his unimitable way, he has obtained the complete series of Sky Buddy receivers and writes a detailed account of how one goes about restoring them with original parts, some 50 years after their manufacture. Most particularly he describes how one replaces the dial belt in a model 5-T, a tricky procedure.

Again we are bringing you *The AWA Review* without charge to the membership. This comes as a free benefit to members—your dues are not affected by the distribution of this journal. *The AWA Review* is the AWA's peer reviewed journal. It serves as a historical record where the facts are verified by one or more anonymous reviewers. That gives it some extra credibility as a source of sound reporting of history. The free printing and distribution of this *Review* are again made possible by a generous donation from a long standing AWA member who wishes to remain anonymous. His gift is an indication that he is committed particularly to historical documentation as a key part of our hobby.

This year's volume reflects a number of trends. One is our continuing use of colour. Not many articles on early radio history need colour, but those that do, manage to make excellent use of it. Another trend in *The AWA Review* is the continuing participation by international authors. This year we have an author from Canada.

This year's volume exhibits a great deal of dedication and energy on the part if its authors. The result is a number of fine efforts, the first described above and then the following:

- **Jaci Grant** had the good fortune to have had a father who was conspicuous in the development of broadcasting, and public broadcasting, in Western Canada. W. W. Grant's early career as a radio designer and manufacturer was marked by legal difficulties. His public notoriety in that period results from his having been sued by Westinghouse and General Electric. Jaci and her family were anxious to tell the more positive side of his achievements, the development of broadcasting in the early days in Canada.

- **Mike Molnar** like all of us, has reflected on the relative impact on wireless and radio development of the great inventors Edwin Armstrong and Lee deForest. In this volume he describes the influence of the two men from the perspective of the century that has elapsed since Armstrong's regeneration patent was first granted.

- **Eric Wenaas** has followed the history of three independent vacuum tube makers who worked outside of RCA. These are Elmer T. Cunningham, Elman B. Myers and Otis B. Moorhead. Their exploits resulted in three articles, of which the third is reported here. Along the way, Wenaas has consulted original documents in the Smithsonian Institution and elsewhere, and reported their findings in great detail. This extensive research allows him to resolve previously unexplained mysteries.

- **Robert Lozier** returns to the AWA Convention year after year, usually with an interesting presentation of some foreign radio equipment. Taken as a series, these exhibited sets indicate a long career of collecting radios not familiar to North American viewers. Why is Robert so interested in them? His article in this volume describes the range of the designs he has collected, and his insights into why they are that way.

- **Mike Adams** has contributed an important series of articles and books, most of them about conspicuous individuals in the evolution of wireless and radio. In this volume he writes about Hugo Gernsback, who emigrated from Europe to America as a very young man. Gernsback was influential in development of radio through the publication of a series of magazines on a wide range of topics. Among many other things, he predicted radio broadcasting.

- **Steve Auyer** worked as an engineer with General Electric through most of his career, but not in consumer electronics. He does have an interest in the way in which transistors made their way into home broadcast receivers. Here he delves in depth into the adoption of transistor technology by home receivers from its very beginnings until the end of production of home receivers by GE.

- **Dave and Julia Bart** report on the influence over 100 years of those who belonged and published in the Radio Club of America and in the Institute of Electrical and Electronics Engineers. Distinguished individuals who belonged to one or both of these societies were destined to have a significant influence on the evolution of the wireless and radio fields. Published papers from these organizations were influential in subsequent developments, which of course was the intention of the organizers.

- **Robert Colburn** witnessed a tornado touch down at a summer camp where he was staying at the age of 11. One might say this stimulated a life long interest in tornado detection. In the article in this volume, Robert explains how electrical and wireless warning systems were used from the early days to indicate the presence of tornados.

- **Bart Lee** is a charismatic author and presenter who contributes most years to this Review. This year he has chosen to mark the impact of the career of Clarence D. Tuska. Tuska began in 1907 as a radio amateur with a metal filings coherer, and progressed through the technologies of the time. In 1914, along with a neighbor Hiram Percy Maxim, he founded the ARRL, and the following year the journal *QST*. He had a radio parts company after World War I, and ultimately was hired by RCA as their patent lawyer, although he had no legal training. Bart recounts the achievements of this amazing man.

Again this year our sincere thanks go to these authors for their fine work. A smoothly finished article often obscures the work that went into writing it, not to mention the time involved.

We continue to use the services of experts in the field as peer reviewers. We believe that this process raises the overall quality of *The AWA Review*. Some of our reviewers have served in this role for a number of years now and deserve our special thanks. The reviewers for this issue are:

David Bart, Erich Brueschke, Neil Friedman, Joe Knight, Crawford MacKeand, Gerry O'Hara, Franz Pichler, Ludwell Sibley, John Terrey, Glenn Trischen, and David Willenborg.

This year book designer Fiona Raven is again involved in the design of the publication. What you see before you is the result of her skilled efforts. She continues to use her templates for the layout of the material. In addition this year, Fiona was responsible for the detailed layout of the information on pages. Again we thank Fiona for her contributions.

AWA members and others with an interest in wireless communication history are encouraged to submit manuscripts to *The AWA Review*. A section titled Tips for Authors follows. We try to make the publication effort more collaborative than challenging. The single most important message in this regard is to contact us early if you are considering writing an article.

A cumulative index of Tables of Contents of all previous issues of *The AWA Review* is maintained on the website of the AWA at http://www.antiquewireless.org.

I have enjoyed receiving and editing your important efforts in historical documentation over the past years. Manuscripts for future years should be submitted to my successor, whose name will be announced in the *AWA Journal*. Manuscripts sent to me by accident will be forwarded to him. I intend to continue to act in some way in the interest of *The AWA Review*. Thank you to all who have supported me in this role, particularly the authors and reviewers, and our anonymous funder.

Robert P. (Bob) Murray, Ph.D.
Editor
Vancouver, BC, Canada

Tips for Authors

The AWA Review welcomes any submitted article on aspects of wireless communications history. In general, shorter articles can be directed to the *AWA Journal* and longer manuscripts to *The AWA Review*. If you are in any doubt about where your article should best appear, please contact the editor.

The AWA Review will accept and publish Letters to the Editor as space permits. This will be a suitable way to submit your comments if you wish to take issue with a recent article published here, or make other brief comments on wireless history matters. Letters will not be peer reviewed, but will be edited, primarily for length at the discretion of the Editor. The Editor reserves the right to publish responses. Galleys of letters to be published will not be returned to the author. Text is limited to 400 words and no more than 10 references.

For first time authors, articles can be prepared with the help of a more experienced co-author, or the editor can help with the text in the editing process. Members with an interesting story to tell should not be discouraged by a lack of writing experience. *The AWA Review* will accept manuscripts in any clearly prepared writing style. A short style manual produced by the American Radio Relay League is available on request. *The Elements of Style* by William Strunk Jr. and E.B. White is available in most public libraries. Reference material should be cited within the text of the article in any of the accepted reference styles. Reference lists should include all of the sources mentioned in the text. Writers should look at the articles in this volume or in recent previous volumes for examples.

Articles submitted to *The AWA Review* will be laid out on the pages in a style made consistent within the entire publication. Therefore, please do not arrange your illustrations on each page but rather send the text in a file separately from the files for each illustration. This requirement applies equally to the Journal and the Review. (see, for example, "From the Editor" in the *AWA Journal*, April 2006, pages 4 & 5.) Text files can be prepared on any word processing software, but preferably on Microsoft Word. Please do not include idiosyncratic text styles (such as small caps) since these will need to be stripped out when your article is prepared for publication. Illustrations are best sent as .JPG or .TIF files with a resolution of around 300 dpi. JPG files should be Standard (not Progressive). Files can be submitted as e-mail attachments directed to the editor.

Manuscripts submitted to *The AWA Review* will be peer reviewed. That is, they will be forwarded to one or more AWA member(s) with expertise in the area of the article. The reviewer's comments will be returned to the author(s) anonymously, so that the reviewer is comfortable with being candid in his or her response. After the reviewers' comments have been addressed by the author, the article will be typeset in a publishing software (currently Adobe InDesign), following which galleys will be returned to the author. This will be the last stage at which errors can be corrected. Normally only one set of galleys will be sent.

Articles submitted to *The AWA Review* should be developed in concept not later than early January of the publication year. A first draft should be submitted around March. The editor's deadline for submission of the completed volume to the printer is May 1. Articles not submitted on this schedule will be rescheduled for the next year's volume. For more information contact:

The Editor
The AWA Review
Address to be announced

W. W. Grant

A pioneer broadcaster in Canada 1892–1968

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Abstract

William (Bill) Walter Westaver Grant, was a true radio pioneer. He began his career as a technician and noted innovator in the early 1920s. He later used a multifaceted approach to bring radio into the public domain. Grant originated the trademark "The Voice of the Prairie" and the historic radio station CFCN in Calgary, Alberta, Canada. Grant burst into the headlines in the very early years of broadcasting. He was often promoted as strong contender in the race for transmission distance. The excitement of those early years was palpable, perhaps even overwhelming at times. In 1943 Grant, reflecting back to the early years, commented that broadcasting took hold of the country with a rush that was almost a panic. His life is a series of snapshots illustrating the development of radio.

Introduction

This project began with the Grant family archive, a collection of letters, documents, pictures, newspaper clippings[1], papers copied from collections from the Glenbow Museum, Calgary, Alberta and a scrapbook of newspaper articles. The scrapbook contains articles clustered around the years 1921–23. Since the majority were for two Calgary newspapers the *Morning Albertan* and the *Calgary Herald* concentration was given to these. Another source of information for the early years of Grant's career is the testimony Grant gave, under oath, during a trial with Canadian Westinghouse in 1926. The transcripts from this trial document his fight to retain the

Fig.1. W. W. Grant in 1922, age 30, from Murray (1992).

right to use Armstrong's regenerative circuit in the W. W. Grant Radio Limited radios he manufactured. They also outline Grant's earliest work with radio. Included in the archive is the information collected by two Calgarians, Ed Burge and Carl Stone who worked tirelessly to document and promote Grant's accomplishments. Their work is filed in the Glenbow Museum. This article is an attempt to study the archive within the context of the times, to collate various family narratives and to illustrate one story from the times of early radio broadcasting.

The Race for Distance

Grant first came to public attention with his great successes with broadcasting transmission. The book, *Listening in: the first decade in Canadian broadcasting 1922–1932,* (Vipond, 1992) suggests that, as radio began to make inroads into public awareness, intense focus was placed on broadcasting distances. It was only later that the public began to realize the true potential of radio was as 'an entertainment medium'. Grant was a strong player in that beginning race for distance.

During October, 1921 Grant maintained contact with San Francisco from both his home base of High River, Alberta and from Edmonton, Alberta in a series of radio-phone contacts. Newspaper articles from the time recorded the excitement and wonder of those who were witness to these transmissions. Headlines such as, "Concert At San Francisco Heard Clearly at Edmonton." documented the events and the content of these articles fanned interest in the new phenomenon of radio transmission (1921). On February 8, 1922, Grant conducted a two way conversation with the Reynolds Radio Co. of Denver, Colorado. This was noted for both the distance covered and for the length of the contact ("Record Wireless Conversation.", 1922). During this two way conversation Grant and his contact Dr. W. R. Reynolds, spent their time discussing ongoing engineering and technical experimentation. Recognition of Grant's accomplishments reached across the country when this feat was noted in a Montreal, Canada newspaper a month later ("Big Growth.", 1922). The thrill of the race was stimulating but for Grant, the desire to define the parameters of the medium was even stronger. According to Vipond (1992, page 192), technical experimentation was ongoing and helped to 'define and achieve the best service'.

Grant continued with a string of contacts throughout 1922 but November was a particularly notable month. Boston, Brooklyn and Hartford on the East coast were reached. These contacts were spoken about as being record breaking, citing a distance of 2,700 miles ("Albertan Radio is Heard in Boston and Hartford.", 1922). By November 23, 1922 Grant had reached Dallas, Texas. This contact was mentioned in the *Dallas Morning News* as "an epoch making accomplishment ("WFAA Talks.", 1922)." The *Morning Albertan* described this feat as a world record for the consistency and distance reached in a two-way radio talk ("Albertan Radio Creates.", 1922). Grant's successes during 1922 were widely recognized. By November it was reported that 972 letters and 11 telegrams from all parts of North America had arrived within a three day period ("972 Letters.", 1922). On December 18, 1922 an ongoing contact with Troy, N.Y. was established ("Albertan Radio Heard Regularly.", 1922).

By the end of 1923, Grant's broadcasts had reached Britain. This was considered to be another record breaking feat:

> Six thousand miles from Calgary, on the night of September 23, H. W. Soase, of 38 Narthgate, Darlington, Durham, England heard the broadcast of the service of the Grace Presbyterian Church in Calgary, which was broadcast over CFCN and W. W. Grant radio. This establishes a Canadian record for long distance broadcasting and is the first time that any Canadian or American radio broadcast station west of Montreal has been heard on the other side of the Atlantic ("Calgary Radio Sermon.", 1923).

Grant thrived on the recognition and praise he garnered from the success of these years but winning a distance race was not his goal. It was only the beginning to his plans. Before further investigation into his role in the development of radio we will step back in time to examine his earlier history.

Grant's Early History

Bill Grant was born in 1892, the third of four children. His mother, Adeline, was a descendent of a group of immigrants from Germany and France. The group, referred to as *the Foreign Protestants*, settled in Nova Scotia during the mid 1700s. Grant's father, William, was from Aberlour, Scotland. He served as corporal in the Royal Engineers and was posted to Halifax 1882. Adeline and William married in 1884 and travelled to England, Ireland and Gibraltar while William Sr. pursued further training. Although this was not a family with a tradition of formal university education, learning was valued.

In 1895, the family returned to Halifax and moved into the blue-collar enclave of the Richmond District. Billie started school in 1899 at the Army Children's school. In 1906, he transferred to the Halifax public school system. His formal education ended in 1911 after a two-year electrical engineering course at the Nova Scotia Technical College. These were exciting times for an inquisitive, mechanically oriented, young boy. Billie's interest in radio started early. As a boy, he built wireless outfits and entertained his schoolmates and teachers with demonstrations. Billie was also very interested in flying. In 1907, *Scientific American* offered a trophy for the first public flight over a measured course of one kilometer. Grant, fascinated with any new technology, reacted with enthusiasm. He devised his own winged device and tested it with an unsuccessful leap from a barn loft. Unfortunately his only reward was a broken arm.

Grant moved to Alberta in 1913. When asked why he had picked Alberta, he replied that he felt this was the best spot for radio transmission and reception in Canada. By 1914, Grant, unlike most other amateur radio enthusiasts, was purchasing expensive tubes from the De Forest Company (*Canadian Westinghouse*, 1926). Even as a young man with limited resources, Grant was driven to use the very best to obtain optimum results.

Grant's Training Ground

World War 1 began July 28, 1914. By September of that year, Grant had enlisted in the 1st Canadian Divisional Signal Corps; the first Canadian contingent to deploy overseas. He later transferred to the British Royal Flying Corps (renamed the Royal Air Force during the war years). He did development work on electrically heated clothing for flyers and served as an aerial photographer. One of Grant's early jobs was as a spotter accompanying pilots to warn of danger. In addition to his assigned duties, Grant, on his own initiative, decided to copy the German spotters' wireless codes and keep records of their shots. This documentation eventually gave him enough information to break their codes allowing him to save a French regiment from heavy casualties in a German artillery bombardment. He received the French Medal Militaires[2] for this achievement (Grant, R., 1985).

Fig.2. Grant in France during World War I with aircraft.

Grant's work with wireless communication during WWI had significant relevance to his later success. While stationed in France, Grant moved up the ranks to become second in command of the wireless and telegraphic experimental section of the Royal Flying Corps. This section employed 300 radio engineers and manufactured 80 per cent of the wireless equipment used by the British forces (*Catalogue,* 1922). Although given leadership responsibilities with the squadron, Grant continued to be an innovator in the ongoing experimentation and development of communication technologies. He was gazetted in the field as an Experimental Officer in recognition of his achievements in this role (*Catalogue,* 1922). During this time, he invented the Clapper Break[3], a device that increased the communication capabilities between ground troops and air support. In practical terms, this device allowed a squadron to communicate with 18 planes instead of two or three. Grant described the Clapper Break in the following way:

> In the early days it [the wave] might extend from 200 to 400 meters and the whole secret—the whole thing that allows more than one station to operate relatively in the same area is the fact that they would use different wave lengths. I narrowed the actual wave to get in more stations in a certain band of wave lengths (*Canadian Westinghouse*, 1926).

Meulstee (2000) described how it was a modification to the armature of the Sterling Break (Figure 3) to increase its frequency of vibration (Figure 4). This modification was applied to the small 30 Watt spark transmitter carried by the British observation aircraft.

Bradbeer (2004) provided what I think is a somewhat clearer explanation:

> The clapper break was a way of varying the pitch of a signal sent by the aerial observer. A ground operator could distinguish one

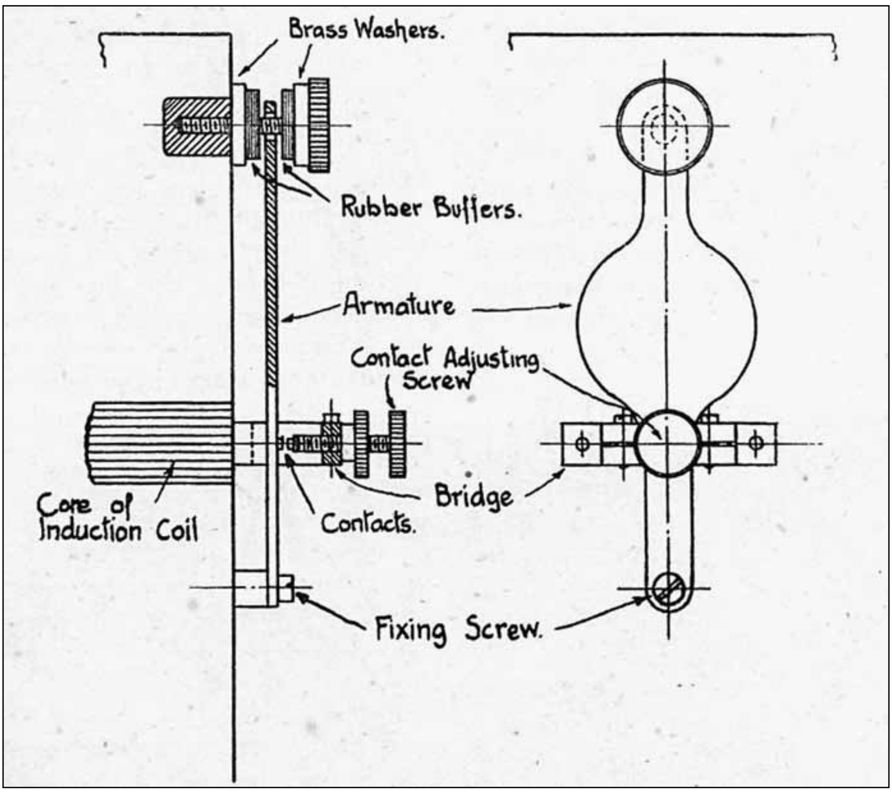

Fig.3. Sterling break from Honan (1919, page 217). The Sterling break was provided with the Sterling 30 Watt aircraft spark transmitter used as Aircraft Transmitter Mk. I by British forces.

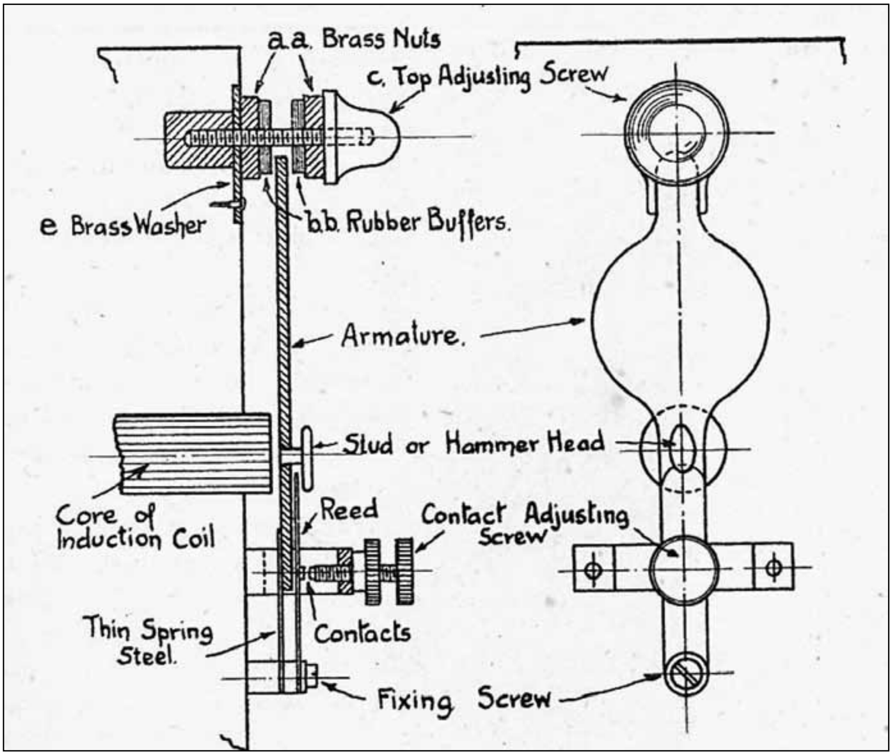

Fig.4. Clapper break from Honan (1919, page 218). The clapper break was a modification which allowed this transmitter to send signals with varying pitch.

aircraft from another working on the same wavelength. He adds, in April the Third Wing (whose personnel developed the clapper break) proved that one wireless aircraft could cover nearly 2,000 yards of trench line without fear of causing interference to another aircraft's communication set.

Grant reflected on the contribution of these war years to the development of radio saying, "The radio art was advancing very rapidly as applied to war and there were constant improvements and developments throughout the war." (*Canadian Westinghouse*, 1926).

1917 was a dramatic year for Grant's work in radio. He was chosen to join Marconi and his corps to work on an unidentified military wireless invention. In a letter home dated September 15, 1917, Grant wrote about being promoted in the field to the rank of 2nd Lieutenant on September 2. The despatch is shown below in Figure 5, confirming this. In addition to his professional successes, Grant's personal life was thriving. He married Clara "Classie" Hannah Clemson of Dalston, London on February 5, 1918. William

The War of 1914-1918.

Royal Air Force

2nd Lt. W.W.W. Grant

was mentioned in a Despatch from

Field Marshal Sir Douglas Haig, K.T. G.C.B. O.M. G.C.V.O. K.C.I.E.

dated 16th March 1919.

for gallant and distinguished services in the Field.

I have it in command from the King to record His Majesty's

high appreciation of the services rendered.

Winston S. Churchill

Secretary of State for War.

War Office
Whitehall S.W.
1st July 1919

Fig.5. Despatch from the Front citing Grant for bravery, and signed by Winston Churchill, Secretary of War.

Ernest, the first of Grant's six children, was born October 31, 1918.

In 1919, the young family returned to Halifax, moving into the family home at 48 Kaye Street. Grant set out to establish himself in the world of radio. He built radios using tubes he had brought back from France or purchased from the Canadian Marconi Company. By the middle of the summer, he had built a small broadcast station capable of transmitting voice and music.

In April of 1920, Grant was hired by the Canadian Air Board[4] as Engineer in Charge of Radio, Radio Branch. During the early years of broadcasting, the Radio Branch became the regulating body for radio in Canada. It's four main areas of authority were licensing, inspection, suppression of interference, and wavelength and power assignment (Vipond, 1992) This early connection allowed Grant to forge a bond with the regulators including C.P. Edwards[5], director of the Radio Branch (1909–1936) and Donald Mason[6], Chief Radio Inspector of the Radio Branch. Mason would later become the General Manager of the Canadian Broadcasting Company (CBC).

Spending a few months in Ottawa, Grant carried out experiments with radio transmission and gathered equipment in preparation for the move west. Transferring to Morley, Alberta, that same year, he quickly built a broadcast station, equipped all planes with wireless telegraph sets and began experimenting with wireless telephony for airplanes. He did not limit himself to work at the Air Board station. By November 1920, he had built a station in Edmonton for a Mr. Burt L. Perry. It included both receiving and transmitting equipment. Mr. Perry was, at this

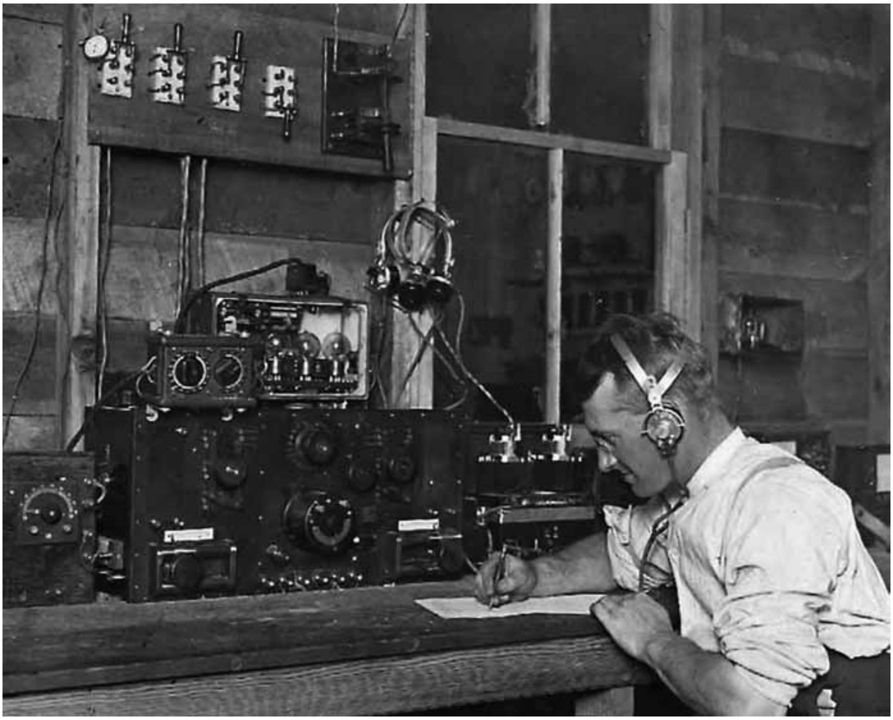

Fig.6. The Air Board station at Morely. Alberta.

time, negotiating with the Hudson's Bay Company for the installation of a communication system for their posts in the North West (*Canadian Westinghouse*, 1926). Grant was drawn into these plans.

In January 1921, the Air Board station was moved to the small town of High River, 37 kilometers south of Calgary. Using the skills and knowledge he had gained during the war, Grant continued to experiment with wireless telephony for airplanes[7]. He built a new and improved broadcasting station and began to have spectacular results with radio-phone communication. Keen to share his excitement, he invited High River residents to take part in his experiments. A loyal group of enthusiasts gathered regularly in his little shack under the towering 212 foot radio mast as he dialed and listened for distant signals. The following is an old timers' description of these High River days:

> Mr. Grant broke the record by assembling the receiver in less than a week and the transmitter in eight days. The receiver had seven stages, the detector was super sensitive and imported from England. The seven stages amplified the incoming signal 1000 times. Visitors were always welcome and Mr. Grant would

> put the earphones in a bowl so all could listen (Stone, C. Genbow Museum Archives, Calgary, RCT 3571).

Grant was already fostering one of the most important steps in the development of radio in Canada, developing an audience for future stations and a market for radio sets. Concerned with more than just a race for reaching distant locales, he dreamed of expanding the medium and bringing radio to the general populace. After his government position Grant worked to promote the grow of radio in three distinct ways. Firstly, he continued to foster a strong and ever growing listening audience. Secondly, he used his ingenuity and knowledge to build an infrastructure of successful broadcasting stations. Thirdly, Grant realized that his listeners needed easy access to a radio set that was more sophisticated than a crystal set with earphones. At the time, such radios were not easily obtained in Calgary. To address this need he began to produce various models of radios under the brand name of W. W. Grant.

Broadcast Stations

Grant began his career in private broadcasting with two infrastructure contracts. The first, was with the Bert L. Perry Company Ltd. Perry was, as mentioned earlier, working on communication development in the far north ("High River.", 1921). In 1922, the *Morning Albertan* showed the progress of the project with articles touting, "Eskimos on either side of the Arctic Circle, in the land of eternal day, danced to musical selections broadcast by the radio station." It was also reported that a Dominion government observation party working in the North West Territories, maintained daily contact with Calgary, with the use of a radio receiver set designed and built by Grant ("Arctic Surveyors.", 1922)

The second contract was to construct a broadcast station for a Calgary newspaper, *The Morning Albertan*[8]. This station, CHBC, began broadcasting on May 18, 1922 at 50 watts (Reid, 1972). The opening was dramatic. Tickets were sold to 1,800 people who excitedly gathered at the Palace Theatre to listen to the broadcast which included a rousing speech from the Mayor of Calgary, music and time checks that were reported to be something never done before ("More Than 1800 Persons.", 1922). Grant's choice of a newspaper as his initial financial backer into private broadcasting was a solid one. The newspaper, as well as providing financial backing, created interest in the growing field of radio and celebrated Grant's accomplishments. It boosted Grant's personal following and helped him to develop standing in the community. As example, during the month of May, 1922, there were several articles with radio as the subject and a regular radio column, The Radiograph Corner. Grant himself was featured in ten articles, started a question and answer column called *Radio*, and by July had written an article titled, "What to Expect From Your Radio Receiving Set." Grant was not, however, content to rely on this partnership alone. Eight months later, he took out an experimental license[9] for his own station, CFCN, using the physical plant of CHBC as his base and continued along a path to total ownership. By 1925, CFCN's reputation was so intertwined with that of its owner that it was often referred to as Bill Grant's station rather than by its call letters[10].

Canada, despite its enormous size (approximately 3,855,000 square miles) only had 6 exclusive radio frequencies. In the early days of radio, there was international agreement that the electromagnetic field, the backbone of radio broadcasting, was a limited resource. They felt that the field should be rationed to reduce interference and to protect national security. All of the Americas had 96 frequencies to share. Canada's allotted six were reused throughout the country from east to west with one frequency per broadcast area. Broadcast time was divided amongst the number of stations in a frequency area. This was a hardship for station owners because it limited the amount of time they could broadcast and made regular, predictable scheduling difficult. Vipond (1992) suggests that this shared time was supported by the Radio Branch. Since the listener was required to pay a $1.00 receiving license fee[11] for each set owned, the Radio Branch felt an obligation to consider the listener as well as the station owners (Vipond, 1992). They felt that this arrangement provided variety for the listeners of the time who were served by weak broadcasting signals and who had limited tuning capability .

After completing the initial construction of CHBC and CFCN, Grant created a string of stations including, CKLC, Red Deer, CJOC, Lethbridge, CKUA Edmonton, Alberta and CFQC[12], Saskatoon, Saskatchewan. Grant's work was not limited to Canadian projects. In 1923 he built a 3,000-watt amplifier in San Francisco, CA[13].

As the years progressed, Grant, unlike the majority of owners during this time period, continued to improve and increase the power of CFCN. By 1928, CFCN had a replacement cost of $150,000, the highest of any of the Canadian stations (Vipond, 1992). This replacement cost is a good illustration of both Grant's focus and one of his greatest difficulties. Driven by his fascination with technological advances, Grant was constantly striving to have the latest and the best equipment, regardless of cost. This trait was not limited to his professional life. He lived an expansive life style complete with expensive cars, cameras and large houses to hold his young and expanding family. His third son Duncan was born in 1922 followed by his daughter Barbara in 1923. During these early times financial difficulties were an ongoing concern both personally and professionally.

During one early rebuild, Grant purchased tubes from the Northern Electric Company that were claimed to be the biggest used by radio engineers. Each tube had a modulating power output of 500 watts. This resulted in a total output power of 2,000 watts. In a newspaper article titled, *CFCN–CHBC*

Fig.7. W.W. Grant station CHBC/CFCN operating room, 1926, from Murray (2005).

Fig.8. W.W. Grant station CHBC/CFCN studio, 1926, from Murray (2005).

To Be America's Biggest Broadcaster, it was reported that:

> When reconstructed, CFCN–CHBC will be an eight and one-half kilowatt station which will be three times as powerful as the one which is at present in operation… Twelve gigantic tubes will be used, the tubes being especially manufactured in Montreal. Instead of one generator, as at present, three will be employed to operate the new station and the powerful generators arrived in the city yesterday. As a comparison to show the strength of the rebuilt station, only three 500-watt tubes are now being used. There will be installed a special amplification apparatus carrying two tubes of 50 watts capacity. The initial input power will be eight and one half kilowatts and the output power will be 1,800 watts, which is the power delivered into the antenna ("CFCN–CHBC." 1923).

C. P. Edwards, Director of the Radio Branch, stated that there were only five Canadian stations broadcasting at 5,000 watts in 1928. By 1932, CFCN was running at 10,000 watts.

To circumvent the advertising restrictions in place during the early days of radio, stations used a number of licenses each with its own call letters. In the 1960s, Grant stated that he thought he had, in addition to CFCN, about ten different licenses. These call letters became known as phantom stations. In a personal letter written in 1962 to Mr. E. A. Weir, Grant gave this explanation:

> As you are no doubt aware that in the early years in broadcasting there was no such thing as advertising permitted under the then existing regulations which were controlled by the Dept. of Marine. Owing to financial straights, sometime in 1925 I think, I conceived the idea of making some revenue from the station, CFCN, and arranged with C.P. Edwards, Dept. of Marine to do this by taking out a separate broadcast license for each advertiser. Some of the earlier advertisers I had were the C.N.R., P. Burns and Sons and Riley & McCormick, a Calgary harness maker. I think I had about ten different licenses for different advertisers.

Grant claimed to have originated the concept of phantom stations. Michael Nolan reports that C. P. Edwards is given credit (1984). It does seem plausible that Grant went to Edwards with the idea since he was an owner searching for financing options to keep his station running. Edwards, according to Vipond, was known to be open to suggestions put forth by those working directly in this evolving world of radio. He could easily have agreed with the idea. Vipond (1992) wrote that Grant collected close to $200 a month in this period from rentals to phantom-license holders.

Attracting and Developing an Audience

Grant had a devoted audience that grew as his broadcasting reach expanded. His keen and committed listeners sent Grant details of the equipment[14] and techniques they used to receive broadcasts as well as the times they heard the radio signals. They asked for program times to be rescheduled to accommodate time differences. They delighted in sharing their locations at times as far away as Cuba or just off the coast of Japan; up and down the coast from Mexico to Alaska, and across the continent.

Some listeners stayed up late to listen and, if possible, contribute to Grant's experiments. The following letter from Nicol Sinclair of Toronto, illustrates a simple type of experiment Grant and his audience engaged in:

> You were talking to WFAA and telling him you were on 375 meters and you were going to raise it ten points, at the same time playing music for a period of ten minutes on each rise… I would like you to let me know if you are likely to be testing again in the near future as I will sit up any night to get you and will also give you a report ("Toronto, Albany, and New York", 1922).

Grant realized that the experimentation that took place in the late night hours had a limited audience. He began daytime programming, scheduled, consistent, and with varied content, to increase and solidify his listening audience. Along with his entertainment programs Grant provided regularly scheduled summaries of local and world news, the stock market, farm reports, weather predictions and politics.

Since home receiving sets were scarce, Grant encouraged interest in the medium by installing, at differing times, both a receiver and a transmitter in the Palace Theatre. Beginning with the opening ceremonies for CHBC, programs were heavily promoted and attended. Broadcasts from the theatre, heard in the comfort of home gained popularity. Music programs were wide ranging including classical singers, rollicking cowboy troupes, piano solos, and guitar and banjo groups. Early broadcast stations had little physical space to house the performers so they were secreted in rented hotel rooms, distant and unseen, adding to the magical feel of radio. The following description from an old time listener, describes a novel experience Grant arranged:

> He was a great feller to tell us what he was doing, had planned, and experiments underway. At this time the Palace Theatre in Calgary was putting on band concerts so he thought his audience should hear them. Well, he assembled his equipment down there on the stage of the theatre and the big night had arrived

for us to listen. He said that he would have to appear with the band to do the announcing and he would be dressed in evening clothes. This part he didn't seem to like but he wouldn't let a thing like that stand in the way of an experiment such as this. Our ears were glued to the radio; seems like only a short time ago. It was a wonderful broadcast and turned out to be a perfect evening. The reception was good and being the first live band I had ever heard, except for the neighbor's Edison gramophone, is perhaps why I remember it so well. After it was over he was back the next day announcing at the station as usual but had a real bad cold. My mother was feeling sorry for him and said that he had caught that cold down there in that drafty old theatre and that he should have known better and kept his heavy underwear on. He put on regular concerts remote from the Palace after that but he never appeared on the stage again. He made the conductor do the announcing[15] (Burge papers, M6287).

Grant did not limit himself to broadcasting from the studio or stage. He developed unique ways to reach his audience. At one point, he used his connections at the Air Board to convince the pilot Elmer Fullerton to broadcast from his Avro Viper airplane. He recited the final chapter in

Fig.9. The Palace Theatre, Calgary, Alberta, from the website of Historic Places in Canada, Parks Canada.

the *Life of Dangerous Dan McGrew* to the CFCN audience (Cashman. 1979). Grant set up equipment at the Fall Fair and broadcast live descriptions of auto races. The broadcasting itself became a news item in the next day's paper. Headlines raved about the races 'seen' on the radio ("Albertan Today Will Use.", 1922).

Audience participation was encouraged by contests. Jack Peach, a newspaper columnist for the *Calgary Herald,* described another type of programming, the call-in show, common today but unique for the times:

> Grant thought up a scheme that involved connecting his home telephone to the station transmitter, inviting people to discuss their problems on the air. It was an idea typical of his imaginative trail blazing. He didn't really undertake the venture to create what is believed to be the first Canadian community radio show. The broadcast took place September 13, 1922. Fans could

hear both sides of the conversation. They asked for solutions to their problems (Peach. 1982).

Grant's programming efforts were successful. According to a Seattle, Washington paper "he was the long distance standby of the local radio enthusiasts." ("W. W. Grant's Radio.", 1922). The Bronco Busters, a program he started, was one of radio's longest continuous running broadcasts. It started in 1923, was renamed Cy Ebenezer and the Kid in 1924, and finally became the Old Timers Show. The Old Timers ended production in the early eighties.

As the years went on, rules and regulations from the Radio Branch evolved to accommodate the Canadian programming that was developing via chain broadcasting and linked stations[16]. This was a positive revenue change for all station owners. Grant was quick to make sure he was a part of this growth. Not willing to trust a long distance request he personally travelled to Ottawa to make sure that his station was one chosen by the C.N.R. line to carry these programs ("W. W. Grant to Establish.", 1924). Stations also sold time spots to individual customers. One such loyal customer was the charismatic "Bible Bill" Aberhart. His Sunday afternoon, *Back to the Bible Hour* broadcast, extended his reach beyond Calgary to Alberta and beyond. This program boosted Aberhart's popularity. CFCN is cited in his successful bid to become the Premier of Alberta in 1935. Aberhart was a faithful client and a consistent, reliable source of revenue for CFCN. A loan agreement found in the Glenbow Museum archive shows

Fig.10. The Bronco Busters, CFCN, Calgary. Grant family photo.

that Aberhart's Prophetic Bible Institute supported CFCN with a $8,000 mortgage during a time of financial difficulties (Loan. M693).

By the late twenties, American programs such as Lum and Abner, Myrt and Marge, and singing duo Billy Jones and Ernie Hare were as popular with listeners in Calgary as they were in the rest of North America. Grant lobbied the Radio Board on their behalf stating that time should be left free from Canadian broadcasting to reduce interference. Soon Grant saw the financial benefits that could be had if he were in control. Murray, (1992) wrote that Grant, "installed a monitoring station close to the U.S. border and rebroadcast the U. S. shows while substituting their commercials with local ones."

Fig.11. "The Voice of the Prairie Four", 1927 version, from Murray (1992).

W. W. Grant Receiving Sets

Grant's ambitions extended beyond broadcasting. In July 1922, he formed W. W. Grant Radio Ltd. a company that manufactured and distributed radios. The catalogue for this company describes four sets: The W. W. Grant Perfection Long Range Receiver (patent applied for), the W. W. Grant Perfection Tuner and Detector (patent applied for), The Grant Local Receiving Set and the W. W. Grant Local with Amplifier (*Catalogue*, 1922). In March of 1925, a second company, W. W. Grant, Limited was formed. In the prospectus for W. W. Grant, Limited, the company is clearly linked to CFCN and its ability to generate money through advertising.

Unfortunately, Grant's foray into radio manufacturing was plagued with problems. A fire in his radio manufacturing facility caused an estimated $9,500 worth of damage and delayed progress with his upgrades to CFCN. On top of the overwhelming responsibility involved in supporting both the technical and the operational side of CFCN, Grant now had a new and very different type of business to manage with both technical staff and a store. On February 2, 1926, Grant and his company, W. W. Grant Limited received two Statements of Claim from the Exchequer Court of Canada. One, initiated by Canadian Westinghouse Company Limited, disputed his right to use the Armstrong regenerative circuit in the manufacturing of his radio sets. Canadian Westinghouse was named as the Plaintiff and Assignee of Howard Armstrong and E. F. W. Alexanderson respectively (Canadian Westinghouse, 1926). The second Statement of Claim indicated that the Canadian General Electric Company disputed his right to use the Armstrong regenerative circuit and the Langmuir tuning circuit in the manufacture of his receiving sets. (Canadian General Electric, 1926).

Ironically, Grant would have been able to apply for his own patent after World War 1 based on his military work. Unfortunately, legal and financial matters were never Grant's priority. Armstrong, by contrast, had protected his interests in Canada with a Canadian patent in 1922. On July 3, 1926, Grant won the case and was granted the right to use the circuit in his broadcast receivers (Murray, 1992). According to R.S. Grant, his father was approached by RCA after this successful outcome. They offered to buy the rights and promised him complete control of distribution for RCA products in Western Canada (Grant, R., 1985). Grant refused RCA's offer.

Shortly afterwards, an appeal was filed by Canadian Westinghouse Company Limited, with the Supreme Court of Canada (Canadian Westinghouse, 1927). As in the first case, Grant's lawyer fought the case based on Grant's early and extensive use of the Armstrong circuit, both during the war and in Canada before the Canadian patent existed. This time the approach was not successful and he lost the case on October 4, 1927. He was required to stop manufacturing W. W. Grant radios, was directed to pay court costs and refund any profits he made in the sale of radios that included the disputed circuit (Murray, 1992). Grant felt that the court's decision was unfair. At this point in Canada's history, Supreme Court decisions could be appealed to the Privy Council of England but Grant had exhausted his resources and was unable to pursue the matter further.

Down But Not Out

The Supreme Court decision was a tremendous blow to Grant, both financially and emotionally. In his day-to-day life, Grant was passionate and dedicated and he expected those around him to share his drive for success. He was often reckless and careless, distant and silent. Always a complicated man, the stresses from his repeated disappointments accentuated some of his more problematic traits. His emotional outbursts and episodic drinking alienated his friends. He often became so engrossed in his work that he ignored his family and his business responsibilities. His poor personal and business decisions led to lawsuits and often brought him to the brink of financial disaster. Although Grant had a complicated personality and not all people remembered him fondly, he had a solid reputation, and was well known throughout Canada. His connections with the founders of the Radio Branch were strong. He had many influential colleagues, clients who supported him, and listeners who were loyal and steadfast.

Devoted and determined, he was not ready to abandon CFCN and his faithful audience. Grant had a strong and enduring bond with his listeners. His audience felt valued and included in the CFCN story because of his inclusive approach to experimentation in the earliest days. The bond grew with his expansion into regular and scheduled programming. Examples of Grant's practices were gathered by Ed Burge in his research collection. In one incident a listener pointed out an error in a broadcast. With a response typical of Grant, he answered with a small gift of thanks. Such responses were valued and garnered loyalty (Stone. RCT 3571). Another listener, looking back, said he never forgot how joyful Grant sounded after successfully increasing the broadcast range of CFCN. Grant also poked fun at himself; once relaying an incident when he fell asleep rolled up in a rug, interrupting the ongoing production with loud snores and making the cast roar with laughter in the middle of their broadcast. Grant not only shared happy, silly times but also shared his disappointments. In particular, the night he expressed the distress he felt over losing the right to manufacture his radio sets was cited. Such honesty garnered sympathy. Grant's listeners respected his talent and shared in his successes and his downfalls. Farmers and ranchers often showed their appreciation by arriving at the Grant family home with gifts of poultry, meat, and eggs (Grant, R., 1985).

By 1928 Grant was in severe financial difficulties and was forced to consider selling his beloved CFCN. Grant, trusting and naive, the antithesis of a clever business man, was in desperate straights. After months of talks exploring different options including a proposed $13,000.00 deal with the Alberta Pacific Grain Company and continued negotiations with H. G. Love, CFCN was officially sold on January 30, 1929 to Love who then formed a new company, *Western Broadcasting Company Limited* (Brownlee, Porter & Rankin 1929). Grant had given up his patented name, "The Voice of the Prairie" which was synonymous with CFCN and the physical plant. He also promised to remain as engineer for three years. Although mentioned as part of the sale, the broadcast license[17] for the station, remained in Grant's name. It is likely that promises had been made, that Grant looked upon this as a temporary state of affairs.

Love and Grant were cronies from years back. The friendship must often have been a strained one since Love, an employee of Canadian Westinghouse, is credited as being the possible catalyst for the patent dispute of 1926 (Murray, 1992). At the same time, there were years when they worked well together. Sometime after 1931, when Grant's exclusivity agreement was over, he again became an owner of CFCN, this time in a partnership with Love. A new company was formed, The Voice of the Prairie Limited, with each controlling 50% of the stocks. Love's name was officially added to the broadcast license during this year. Grant's understanding of their respective roles was clear, "I devoted myself to the operating end of the business and H. G. Love was in complete charge of the business and financial end (Director of Radio, 1935).

Grant's focus on the development of radio evolved during these partnership years at CFCN. Adding to his punishing work load of 18 hour work days he began to delve deeper into the political sphere. Grant and Love appear to have had three areas of focus in their quest to make CFCN a key station within the Canadian broadcasting system. Since stations in Canada were still forced to share time on one frequency, gaining a priority single station license was vital. Increasing broadcasting power would expand the station's reach and reliability. Both would guarantee the more steady revenue base necessary for continued viability. It is probable that the first two goals were in preparation for the third and ultimate one, gaining affiliation with one of the American networks. Grant set out to insure these three targets were met.

Letter and telegram correspondence from these times show an environment of competition and unrest fostered in part by the continual fight over time spots. In one example, R. B. Bennett, the Prime Minister of Canada, 1930–1935, planned to make his 1931 New Year's broadcast (a two-way talk with the Lord Mayor of London, England and an address to the Boy Scouts of England) from Calgary[18]. Grant knew Bennett well from his early years as a client of CFCN and was expecting to provide the broadcasting time only to see other Calgary stations jockey to gain the privilege. Unsure of the final answer, he made sure to meet Bennett's train to fill him in on the situation. In a later telegram to C. P. Edwards, Director of Radio, he explained that Bennett had confirmed that CFCN was to be the station in control and was 'much annoyed' at the rival station's 'piracy methods' (Calgary Telegrams. 1930). This casual meeting at the train station turned into a sharing session lasting into the wee hours of the morning and ended with the words, "You have nothing in this world to worry about Grant—Remember, you have a friend (C.P. Edwards, 1931)."

Several months later, after a year with no progress, Grant travelled to Ottawa, to personally lobby the Federal government for 1) permission to increase CFCN's power to 10 K.W.[19] and 2) an exclusive license.

Throughout this visit to Ottawa, Grant was aware that his requests could influence policy. As a part of his plea for increased power he said,

> "I myself cannot see how the granting of this permission to increase our present power would in any {way} jeopardize any of the government's future policy, although I feel that in return for doing this, we should be more or less assured of fair compensation if the government should eventually take us over (Director of Radio, 1931)."

The application for an exclusive frequency and an increase to power was successful. In April of 1931, CFCN was given full time, exclusive broadcasting rights (channel 985)[20] to a station of 10,000 watts. CFCN was one of the first stations in Canada to be given these rights. The station was built with an eye to future expansion with a guaranteed power source which would support up to 100 K.W. should it be needed. Another part of the request, compensation to be given if the government should ever take over the station, was never given[21].

In 1932, Grant is listed as a witness on the cover page of the *Minutes of Proceedings and Evidence, No. 8*; *Special Committee on Radio Broadcasting* dated April 6, 1932 for Session 1932, House of Commons, Ottawa (1932). This report discussed three different areas: i) programming, ii) a change in infrastructure from telegraph to telephone lines, and iii) a station rating system. Grant advocated for specific improvements funded by increased licensing fees. He discussed the advantages of providing fifteen hours of continuous broadcast per day, and promotion of local Canadian talent. As well he suggested providing four to five hours of the best of American programs as a way of insuring loyalty to local Canadian stations. Interestingly, though he had been an early proponent of advertising, Grant now felt that advertising on radio should be curtailed for the benefit of the listening public (Papers. M693).

Even with the monetary resources that Love was able to provide, money continued to be an issue for both the station and for Grant personally. By 1936 the working relationship between Grant and Love had deteriorated dramatically and on May 7, 1936, Grant signed the papers for the sale of the 50% of the shares he owned in the company, *The Voice of the Prairie Limited* (CFCN). Grant had most likely contributed to his own downfall but he felt betrayed—a feeling that lasted his lifetime.

The months following were difficult for Grant. Having promised not to take out another license within a reception radius of 500 miles of Calgary for five years or to be an employee of any broadcasting operation within the same area for two years only increased his difficulties and his future looked bleak. On top of his professional problems, Classie, his wife, bedridden and cared for at home after months of expensive treatment at the Mayo Clinic in Rochester, MN, died March 14, 1937. In a letter dated, February 28, 1937, Nellie McClung, a prominent Canadian feminist, politician and social activist, wrote to Grant expressing concern over his drinking problem (McClung. 1937).

Grant married his second wife, Florence Hutchison, December 24 of the same year uniting his son Raymon (Dec. 6, 1930) with his four half siblings. Raymon remembered those days as difficult with monetary difficulties making it a struggle at times to put food on the table. The marriage was a stressful one and the Grants separated not long afterwards. Happily, they reunited in the forties and remained together until his death in 1968.

Grant Moves to the Public Broadcast System

The Canadian Broadcasting Company (CBC), a crown corporation, was formed on November 2, 1936, assuming the assets and principal functions of the CRBC. Their plans for four high powered and strategically placed regional transmitters were carried forward. Grant was hired as a consultant, then Technical Supervisor and finally Chief Engineer for CBK, Watrous, Saskatchewan (50

KW). He had officially moved from the private to the public system. The station formally opened in the spring of 1939 despite the challenges of temperatures that plunged to -50 F degrees and blizzards that buried the station in snow. The build was a success and Grant's skill with tweaking equipment to obtain extraordinary results[22] and save costs was often called upon. The CBC publication *Radio-TV* described the station as having a reach from western Manitoba to mid-Alberta to Texas (L'Ami. 1964).

One could assume that this move to the public system was one of necessity but examination of Grant's leanings in the preceding years show that the tenets of the corporation were similar to his; one could postulate that he had helped form these very policies. The Saskatchewan location, chosen with reasons similar to his original choice to locate in Alberta[23], the support of colleagues, and the opportunity to work on a station so much more powerful would have made the move quite palatable.

As a new corporation the CBC was working to establish itself as a truly national broadcast system. The Royal Tour of 1939 was one of the first opportunities to do so. Grant, with expertise based on his early efforts and experience with 'in the field broadcasting' was called upon to give support. This tour was a huge undertaking lasting for one month with daily broadcasts to both Canada and the world. Travel was by train and the tour visited every province, the Dominium of Newfoundland as well as spending three days in the United States. In his letter of thanks, Murray Gladstone, General Manager of the CBC, asked Grant to accept a cigarette box in recognition of the 'efficiency, enthusiasm and perseverance' he had displayed and described the event as 'perhaps the biggest job ever undertaken by any broadcast organization'. Vipond, (2010), in her essay, T*he Royal Tour of 1939 as a Media Event,* describes the tour as meeting its goals, commenting as well that, "the fledgling public broadcaster spent a huge amount of time, money, and effort on the tour, and it all came off almost perfectly". Grant's expertise supported and added to the success of the CBC in this milestone event.

When WW II was declared in September 1939, Grant immediately offered his services. In a letter to a Calgary friend, Mr. McCormick he said:

> Well here's the latest from this screwball yours truly: I was all lined up on a job of acting as navigator ferrying bombers across the Atlantic several months ago when the CBC tabooed it by refusing to release me. Now, instead I am all signed up to go over to England for the RCAF in connection with the defense of London.

Grant was released from the CBC and became a Specialist Officer in the Royal Canadian Air Force (RCAF) with only sporadic visits to London. Given an assessment of A plus, his enlistment papers remarked that he was "an outstanding candidate, thoroughly qualified and highly recommended, probably one of the most experienced men in Canada in his field." Initially he served as a Flight Lieutenant spending time at the Trenton Flying School; later serving as Squadron Leader supervising the repair, maintenance, and installation of the forces radio equipment in Canada. Although Grant served almost exclusively in Canada he was not spared the ravages of war. Duncan "Bitsy" Grant, his third son, followed in his footsteps and became a pilot. When he was killed in France on September 25, 1943, Grant was devastated.

In 1944, Grant returned to the CBC to contribute to the final stages of CHTA, the new international shortwave station being built in Sackville, New Brunswick. He was in charge of the massive, 380 foot steel towers and aerial arrays built to withstand a Maritime gale of one hundred and twenty miles an hour. He also contributed to the experimentation with distance transmission. Reports that filtered back from Europe suggested that the station was a success, that the Canadian shortwave signals were the strongest heard from the Americas (Radio. 1945).

The Sackville years were healing ones for Grant. Reunited with his wife Florence, his youngest daughter Jacqueline, was born when he was 53. His work was interesting and fulfilling. Finally, Grant had found, for the most part, balance and contentment to life.

Grant returned to Alberta in 1947 to oversee the construction of CBX (1010), another in the CBC series of high power transmission stations. Located at Lacombe, he remained as Chief Engineer until his retirement from the CBC in 1958. In 1953, taking a three month leave, he built the station, CKLC (1380) in Kingston, Ontario for his son, R.S. Grant. This station became his retirement base in 1958 and he worked there as Chief Engineer for seven more years.

Grant changed greatly over the years. During this time with the CBC he had time for his family—to joke and laugh and play, to guide and support. The hard driving young man was replaced by a thoughtful and studious leader. He was diligent in his role as head of CBX and supportive of the CBC and the corporation men who had championed and respected him over the years. He enjoyed the camaraderie of daily interactions, but his life still centered on his work. He was friendly in informal situations but did

Fig.12. Retirement from the CBC in 1965, with wife Florence.

not engage in formal small town social institutions. There was time for his hobbies, golf and photography. Even with these he enjoyed pushing the limits and systematically experimented to devise a formula for colour film development. His past still haunted him during his sporadic periods of heavy drinking. It was only during these times that he expressed his intense feelings of betrayal over the loss of CFCN and his anguish over the Armstrong lawsuit. Grant may have been bitter but he was also fair. Though deeply hurt by his legal battles with Armstrong, he still recognized his genius and praised Armstrong for the development of FM radio.

Grant died in Kingston, Ontario, on March 3, 1968, at the age of 76 while still working on a recent patent application for improvements to “a conventional rotary pump.” In his later years Grant was a self-contained man of few words, who had little interest in self-promotion. He rarely shared his story, generally keeping his memories to himself. A folded and worn copy of Rudyard Kipling’s poem *If* was found among his possessions. It appears that the words of the poet provided solace and perhaps even given Grant direction and strength through those trying times in his life’s journey. His life had been difficult but there were many triumphs and successes.

Conclusion

From the earliest days of radio Grant had a vision. He believed that radio would enhance both daily lives and the greater society. He worked tirelessly to bring this vision to life incorporating ideas from both the British and the American systems recognizing that Canada had a unique set of needs.

He started his career in radio surrounded by the initial policy builders, the men of the Radio Branch. Policy evolved in lock step with technological gains; the Radio Branch was known for listening to the discoveries and thoughts of those on the ground. Grant’s burning need to increase power to ensure good reception that reached as many people as possible was embraced by those in control. It was felt that radio could help unite the Canadian population, a population widely spread across a large land mass. Indeed, by the time the Canadian Broadcasting Company (CBC) was formed plans were solid for the provision of key high powered stations throughout the country to guarantee coverage for all. Grant also used more formal and political approaches to promoting the growth of broadcasting as illustrated by his presentation to the Special Committee on Radio Broadcasting, April 6, 1933. Many of the ideas he shared such as limitations on advertising, associate stations, promotion of Canadian talent, promotion of a good news service, and stations carrying American programming are still CBC policy.

Grant’s work in establishing the broadcasting station, CFCN as a premier station may not have turned out as he would have wished, but his decision to chose Love as a partner to bring his dreams to fruition, did guarantee the success of the station. CFCN remained as one of the key players in Alberta broadcasting, as both a radio and television station until the early ’90s when the radio division was sold. The call letters CFCN live on albeit with the successful television branch. One of the programs he started in 1924, the Old Timers Show (originally called Cy Ebenezer and the Kid) remained on the air until the 1980s.

Grant was one of those hands on, in the field men who helped translate academic theory into the medium of communication we know today. During the earliest years of radio amateurs and professionals alike were testing the limits of the field. Grant’s calculated choice of broadcasting location, his magic touch with all things technical[24], his punishing schedule and his diligent and systematic approach to experimentation with long distance transmission gave him results that were recognized across Canada and the United States. The radios that he produced during his brief stint in manufacturing are collectors’ items and samples are now stored in the National Museum of Science and Technology, Ottawa, and the Glenbow Museum, Calgary.

In 1942 Grant was chosen as a member for the Twenty Year Club of Radio Pioneers, New York City. In looking back today one could second this nomination and state that he was truly one of the successful pioneers of early radio transmission. For Canadians, Grant was a man with influence in the development of both the private and public sectors of radio development, a task few accomplished. As such, he was truly of one of a select few, and can be considered a “Canadian Founding Father of Radio.”

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Notes

1. The newspaper articles show the progression in public understanding of the medium of radio. The earliest articles use language reminiscent of reporting a circus or magic show. They compared Grant to a human spider climbing the aerial masts and broadcasted music as 'a Hallowe'en prank with a gramophone hidden under the bench'. Grant was often called a wizard. As well, the language was lofty and flamboyant,"across towering mountain ranges and great stretches of sea and prairie." Over time, the journalistic style changed, reflecting the society's acceptance and growing expectations for the new medium.
2. This medal is mentioned in a family archive newspaper clipping from the Ottawa newspaper the *Evening Citizen,* Ottawa ("Father of 'Bitsy", 1944).
3. In his book, *The Early Development of Radio in Canada 1901–1930*, Murray describes the clapper break and indicates that it was discussed in an unnamed article in *Wireless World,* July 1919 (Murray, 2005).
4. The Canadian Air Board was a branch of the Department of Marine and Fisheries of the Federal Government.
5. Charles P. Edwards was the Director of the Radio Branch, Department of Marine and Fisheries from 1901–1936. Grant and C.P. had regular contact throughout Grant's time in commercial radio. This was an important contact since C.P. was a strong directing force in the development of radio in Canada. Edwards had certain biases because of his British background but he was open to suggestions and could be flexible in interpretation of rules and regulations. Some suggest that those who had the ear of C. P. and his inspectors got preferential treatment (Vipond, *1992*).
6. Donald Mason was also the secretary for the Aird Commission, a commission set up in 1928 to study broadcasting in Canada and make recommendations for future management. Later, he became General Manager of the CBC.
7. Grant was involved in two court cases in the mid twenties over his use of the Armstrong circuit in his radio sets. During WW1 patents had been suspended to support the Allies in the war effort against the Germans. Grant used and modified the Armstrong circuit extensively during these times. He continued to use this technology, for both the Canadian government and himself after the war unaware that he was in violation of the patent laws that were once again in effect.
8. Radio stations at this time were typically owned and operated by auto supply companies, newspapers, religious groups or radio associations. They were often

loss leaders for their owners, a sideline to their primary business. Newspaper publishers were the most stable of this group and known to invest more.

9. Licenses for broadcasting plants were given out readily at a cost of $50.00. These broadcast licenses, however, are not to be confused with the frequency or wavelength licenses that were rationed strictly. Grant himself believed that early entrance into licensing gave him a step up in the chronological priority chain. Vipond (1992) acknowledges that preference was given to the pioneers of Canadian Broadcasting Years later, in 1931, Grant was granted an exclusive use license, frequency 985, for CFCN.
10. In 1925, a *Radio News of Canada* article asked listeners to compile listening diaries (Vipond, 1992). One from Manitoba listed all stations by call letters except for CFCN. It was simply Bill Grant's; his name was synonymous with CFCN.
11. A receiving license was required in Canada but there was confusion since Americans did not need one. By 1922, the Canadian law was beginning to be enforced ("Radio Telephone.", 1922).
12. This station was constructed in 1923 for the Electric Shop Ltd. A Saskatoon newspaper article described it as having aerial poles 60 feet high with the aerials themselves 140 feet long in four strands. Instead of what was termed 'an old fashioned ground system', a counterpane method was used and was said to be doubly effective. Equipment listed for the broadcast system itself was: a helix, two transmission tubes, and a super sensitive microphone. A two stage receiving apparatus was included in the sending outfit.
13. In addition to building the amplifier, in February of 1923, Grant made a broadcast from the radio station of the Mercantile Trust Company, Telegraph Hill, San Francisco to the delight of many Calgary fans ("W. W. Grant, Speaking.", 1923).
14. Samples of equipment descriptions from letters sent to Grant in the early twenties:
    - 1) Reinhartz tuner with a two stage amplifier
    - The tuner is a single circuit regenerative consisting of a one tube Remler vario-coupler with .001 variable condenser in ground lead. Stromberg-Carlson phones were used. The aerial is a one-wire inverted L 140 feet long, 100 feet high at the far end and 65 feet lead in. The aerial points in a southwesterly direction. The ground is a one-wire counter-poise, 125 feet long.
    - My set is of home construction using a Mullard tube detector and two radiotions as amplifiers with spider web and duo-lateral coils for tuning; a two vario-meter regenerative set and one stage amplification.
15. This was a recollection of an old time listener found in the collection of Ed Burge. He collected information for a book that he was writing on the life and achievements of W. W. Grant. This book was never completed.
16. Canada's first network type programming was chain broadcasting. The Canadian National Railways [C.N.R.] among others, branched into this using their telegraph lines to transmit pre-developed

programs. Later the CBRC developed programs as a part of its mandate. All of these either disappeared or were gathered into the fold of the CBC when it was formed in 1936.

17. According to section 21 of the broadcasting license, the holder of a license could not, without the consent of the Minister, sell the rights of that license. However, if approached, the Radio Branch did have unofficial power to cancel one license and issue another (Vipond. 1992)
18. A few words from Grant's introduction to this program explain why the spot itself had been worth fighting for, "This broadcast was being carried by the Canadian Broadcast System, by the Columbia and National Broadcasting Systems in the United States and through the agency of the Marconi Beam System in Great Britain to an approximate total of 170 stations" (Introduction to radio broadcast, 1931).
19. In his supporting argument citing the difficulties Canadian stations were having with interference from American broadcasting Grant suggested that there was an area of over of 100,000 miles that was unable to receive a Canadian station after sunset and that the Calgary area was particularly badly effected by this.
20. In 1992, the radio station CFCN (1060), was sold by Maclean-Hunter and lost the call letters CFCN. They remained with Maclean-Hunter's sister TV station and are in use to this day.
21. Interestingly this truly became a moot point since the Canadian system never did evolve to one of total government control remaining to this day a mix of the Canadian Broadcasting Corporation (CBC) and privately owned stations.
22. Grant wanted the best and latest in equipment but only felt satisfied when he had pushed it to the known limit or beyond.
23. Grant had chosen Alberta because of its geographical attributes. In Saskatchewan geography provided a salt marsh with conductivity almost as good as the ocean itself.
24. Grant maintained a somewhat legendary status in Calgary for many years. In 1981, sixty years after his beginning years, an article written by Terese Brasen for *Alberta Magazine* stated, " He was a technical genius and had a way of building a transmitter that made the radio waves extra powerful." Later she said, "Grant had built the CFCN transmitters in an incomprehensible but obviously brilliant way." (Brasen. 1981).

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Barry Grant, grandson of W. W. Grant, did an initial search for information at the Glenbow Museum and shared all that he found. Michael and Donna Grant of Calgary provided support for the research time spent in that city. Other Grant's shared materials and gave comment as the work progressed. Friends listened and supported. To all of them, my appreciation and thanks. To my husband Moti who supported my endeavors throughout this writing process, "I couldn't have done it without your support."

About the Author

The author, **Jacqueline Grant**, is the youngest daughter of the subject of this article. A graduate of the University of Toronto with a B.A. degree in Sociology and Psychology and Specialist qualifications in Special Education (York University), Reading and Early Childhood Education (University of Toronto) she was a teacher and consultant for 35 years. Now retired she has had time to delve into Grant family history and the path of her father's career. It truly was a journey of discovery. Although not a witness to the beginning years of radio development or knowing the full story of her father's journey his intense focus on the medium was well understood. Grant, just as he had in those early years with his audiences, fostered an appreciation and wonder for the medium in his daughter that has lasted throughout her life. The author was gratified to find how closely childhood memories of adult conversations and the scraps of information her father had shared matched the facts uncovered while writing this article.

Jaci Grant

PATENT BATTLE

Armstrong v. DeForest

Abstract

- Everyone with an interest in the history of radio and electronics knows that Edwin Howard Armstrong was one of the greatest inventors of the 20th Century.
- Everyone with this interest knows of his great inventions—Regeneration (feedback), the Superheterodyne and Wideband FM radio.
- Everyone who has seen the regenerative patent tags on the earliest broadcast radios would know that the regenerative circuit was his first great invention.
- Everyone knows this except the United States Government, the US Patent Office and the United States Supreme Court.

This article will follow the battle for the patent on regeneration which would span parts of three decades.

It is common to think that the legal tangle over patents and royalties is a modern phenomenon. It is not. Patent battles started with the creation of the patent laws. Rarely is any inventor free from the challenges of interference claims from other inventors. Rarely is any inventor free from legal challenges. The more valuable a patent, the more likely the challenges. Famous inventors such as Thomas Edison, Eli Whitney, Alexander Graham Bell, the Wright Brothers and many others were not immune to the legal entanglements of the patent laws.

This year 2014 is the 100th anniversary of patent # 1,113,149 being issued to Edwin H. Armstrong. In simple terms, his patent took the audion tube that was invented by Lee deForest and by feeding back some of the output to the input greatly increased its usefulness as a wireless amplifier. From a technical viewpoint this would be a very important invention. When wireless would change to radio and radio would boom in popularity, this would become an extremely valuable invention. As more inventors were investigating improvements in wireless the invention of a feedback circuit may have been inevitable. As many as 14 claims were made to the original idea of feedback or "regeneration" as referred to by Armstrong.[1] Eventually the patent office tribunals would reduce the claimants to two. And the two would do battle with the prize changing hands from 1914 to a final Supreme Court decision in 1934.

Lee deForest, born on August 26, 1873 to a religious and teaching family, would be the challenger. He would claim prior invention. Edwin Howard Armstrong, born on December 18, 1890 to a middleclass New York family, would be the young, lone inventor forced to learn the ways of a legal world new to him, to defend his work. DeForest graduated from Yale in 1893 and received a PHD in 1899. He left Yale committed to finding fame and fortune as an inventor in the new field of wireless. Howard Armstrong, as a student in the beginning of a new century, was also committed to becoming a great wireless inventor. He would join the ranks of the young boys and men learning together through wireless clubs. He would also take the next step to become an electrical engineer and enter the freshman class of Columbia University in 1909. Lee deForest, by 1909, was a veteran of many wireless companies. He had a number of patents as well as experience with the legal system. What would become his most important invention, his 1908 patent, was adding a third element between a plate and a filament in a bulb called an audion. He would battle most of his life to keep that little audion for himself. It was not to be shared with a young newcomer, like Edwin Howard Armstrong. We will follow the major events of the patent battle between these two men that will take us through the final resolution by the U.S. Supreme Court.

Before 1912

Before 1912 Lee deForest was already an established inventor, experienced with many patents including the three element Audion. He had businesses that started and failed and he was experienced in the courts. He had name recognition in the wireless field. Howard Armstrong was an undergraduate studying electrical engineering at Columbia University. This year his name would appear on the membership list of the Radio Club of America.

The equipment that was available for wireless work was primitive. The available detectors of wireless signals included the coherer, Marconi's magnetic detector, Fleming's two element valve, Fessenden's electrolytic detector, Pickard's crystal detector and deForest's three element Audion. None of these had much advantage over the other. The common characteristic of all of these was that there was no amplification of the signal. The only methods to improve the distance and quality of a wireless signal were to increase the power of the transmitter or increase the signal input and efficiency of the receiver. This meant longer antennas and better tuning, but there was nothing available to amplify the signal. The audions available were of poor quality and how they functioned was poorly understood. Lee deForest was working to make an amplifier using audions, but at this time with no success. His goal was to make a line amplifier for the telephone company. Their hope was to use amplifiers to extend telephone service coast to coast.

Also at this time producing a clean, clear and continuous radio signal was difficult. Arc transmitters and high frequency alternators were the best solutions at the time. These were large and expensive devices and wouldn't meet the requirements for the coming of radiotelephony.

Events of the Year 1912

August 6, 1912 DeForest experiments with an audio line amplifier for telephone use. During that work he notices it can produce a continuous squeal in telephones. This is recorded in a notebook by his assistant H.B. van Etten.[2] This entry will serve as deForest's date of his concept of the feedback circuit. He would also continue work to remove the squeal before it can be demonstrated to AT&T as an audio line amplifier.

August 1912 During a vacation with his family Armstrong tells of having the idea for the feedback circuit. He returns home to build and test his idea. He finds that his antenna had been damaged by a storm.

September 22, 1912 Armstrong completes repairs on the antenna. He builds a receiver with an inductance to tune the "wing circuit" of his audion and tests the operation. He notes "great amplification obtained at once". He also notes that, with adjustment of the wing inductance, the audion will oscillate.[3]

October 30, 31, 1912 DeForest demonstrates his cascade audion line amplifier to engineers from AT&T.[4]

Fig.1. Lee deForest with Cascade Audion Line Amplifier.

Fall 1912 Armstrong is unable to raise the fee to apply for a patent. His father refuses to advance him the funds since he believes this is a distraction from his school work. He will only advance the money after graduation. After Armstrong exhausts his financial options, Armstrong's uncle advises him to get a notarized diagram of his circuit to set a date of invention.[5]

Events of the Year 1913

January 31, 1913 Armstrong takes his uncle's advice. He makes a diagram of his feedback circuit and has it witnessed and notarized.

March 12, 1913 Armstrong gives a formal demonstration of the regenerative circuit to Henry Mason his instructor at Columbia University.[5]

June 1913 Armstrong graduates from Columbia University. He begins a job there as a laboratory instructor. His father advances the money for the patent fee. Armstrong consults attorney William H. Davis and begins preparing his patent application.

July 26, 1913 deForest sells AT&T rights to the audion for all uses except wireless for $ 50,000.00.[6]

October 29, 1913 Armstrong's regenerative patent application is filed. It is titled "New and useful improvements in wireless receiving systems"

October 29, 1913 Irving Langmuir of GE applies for a feedback patent on the same day. Armstrong's notarized diagram pre-dates Langmuir's application.[7]

November 4, 1913 Lee deForest presents a paper and demonstrates his Audion Amplifier to a meeting of the Institute of Radio Engineers (IRE). After the first demonstration he is asked to connect two wires from Armstrong's "black box" regenerative detector. DeForest comments that after listening to the loudspeaker, he had "a fair idea of what was in Armstrong's box of mystery".[8]

November 1913 DeForest and business partners go on trial for multiple counts of mail fraud and all face possible jail time.

December 18, 1913 Armstrong, still regarding the oscillator and transmitter

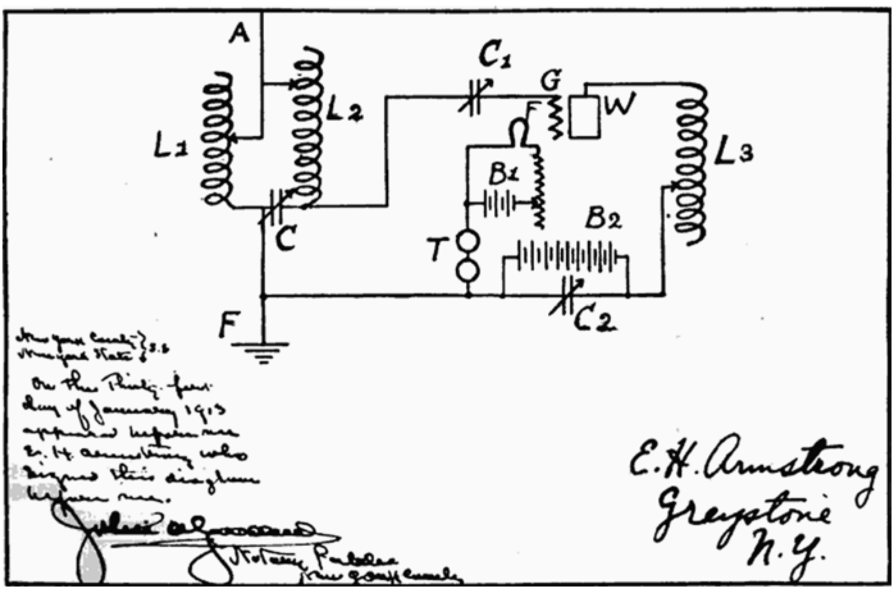


Fig.2. Armstrong Regenerative Circuit notarized 1-31-13.

functions separate from the regenerative receiver, now files for a patent on the oscillator function.

December 31, 1913 DeForest's mail fraud case goes to the jury. He is found innocent but his partners are found guilty.[9]

Events of the Year 1914

January 6, 1914 Armstrong demonstrates his receiver, hidden in a box to Marconi representatives including David Sarnoff. Several weeks later, Armstrong and Sarnoff test the receiver for 48 hours in a cold radio shack on the New Jersey Coast. Sarnoff reports "phenomenal results" and suggests licensing or purchasing the invention to Marconi executive Sir Godfrey Isaacs. Isaacs comments that Sarnoff should be fired for proposing to waste company funds.[10]

February 6, 1914 Professor Pupin at Columbia University arranges for J.J. Carty and other AT&T engineers to visit his lab to see Armstrong's invention. He tells them they will receive a "demonstration of the impossible".[11]

Winter 1914 deForest has an exhibit of his Ultra Audion at the National Academy of Science in Washington. He is generating audio tones through a cascade audion amplifier. Armstrong's mentor Professor Michael Pupin of

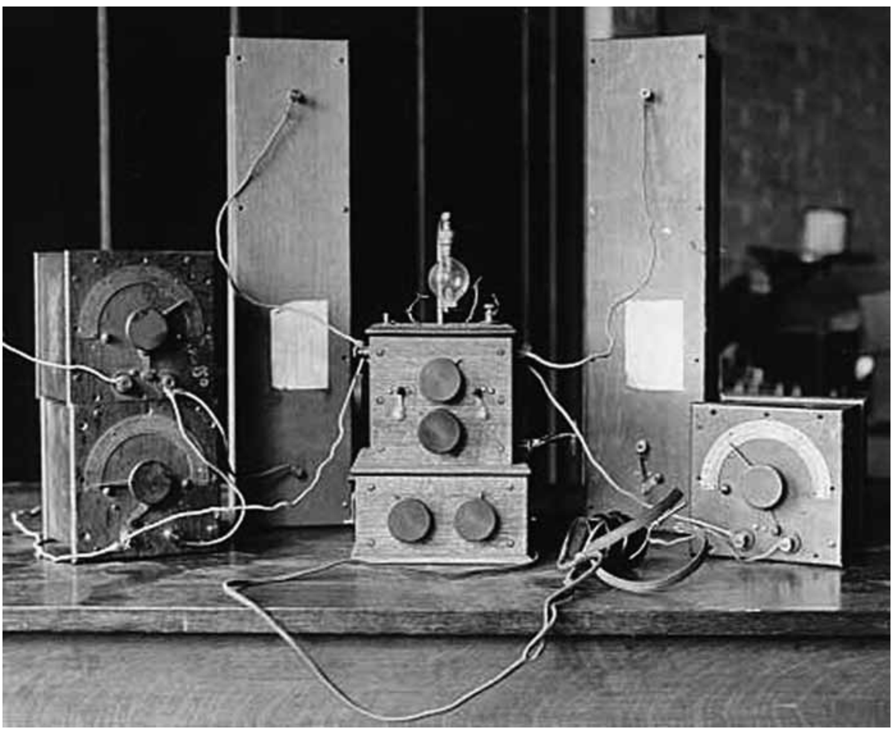


Fig.3. Original Armstrong Regenerative Receiver.

Columbia University confronts deForest. He states, “What right have you to have that here? That thing is not yours. That belongs to Armstrong!” DeForest states that he now realizes what was in Armstrong’s “box of mystery”. He also states that the outburst by Professor Pupin was the opening gun for the bitter patent battle to come.[12]

March 16, 1914 Alexander Meissner files for a feedback patent. Armstrong’s diagram will predate his work.

March 20, 1914 Lee deForest applies for a patent for an Ultra Audion oscillator, an audion device to produce continuous wave oscillations.

April 25, 1914 AT&T engineers return to Columbia University for a further demonstration of Armstrong’s regenerative receiver and to verify the results.[11]

August 7, 1914 DeForest receives $90,000 from AT&T for additional patent rights for non-exclusive use of the audion in wireless telegraphy.

October 6, 1914 Armstrong is issued patent # 1,113,149 for the regenerative circuit.

October 24, 1914 Marconi sues deForest for his audion infringing on the Fleming Valve patent.

November 11, 1914 Armstrong offers to sell the Regenerative Patent to the Atlantic Communication Company for $ 50,000.00. The offer is declined.[13]

Events of the Year 1915

January 30, 1915 The patent office informs deForest that his March 20, 1914 application infringes on the Armstrong patent.[14]

March 3, 1915 Armstrong presents his paper “Some Recent Developments in the Audion Receiver” to the IRE meeting in New York City. This presentation includes descriptions of the regenerative circuit and the audion as an oscillator. This article is published in the Proceedings of the IRE in September. This begins a published correspondence from deForest to the IRE challenging most methods and conclusions of Armstrong. Armstrong answers deForest in the published letters with neither party convincing the other.[15]

1915 The Telefunken Company, due to German ownership, has cable communication cancelled because of the new war restrictions. They license the regenerative patent from Armstrong for $ 100 per month to maintain communications with Europe.

September 23, 1915 Lee deForest applies for a patent for his feedback circuit referencing the August 6, 1912 notebook entry recorded by his assistant H.B. van Etten. This notebook entry would predate Armstrong’s diagram by 6 months.

Fall 1915 AT&T engineers demonstrate their proficiency with the audion. They attach their experimental transmitter to the Navy antennas at Arlington, Va. Using 500 triode audions they sent voice and music as far as Hawaii and Paris.[16]

Events of the Year 1916

April 1916 Armstrong licenses American Marconi to use the regenerative patent for a $ 500 per month royalty.

September 20, 1916 US District Court in New York City rules that the deForest audion infringes the Marconi Company's Fleming Valve Patent. The result is that deForest can't make a three element tube without infringing the Fleming patent and Marconi can't make a Fleming valve with a third element without infringing on deForest's audion patent. Now, after the feedback circuit has made the audion more useful in radio, the court has made it more difficult to produce an audion for radio.[17]

November 1916 David Sarnoff at American Marconi submits a proposal to his superior Edward J. Nally. He suggests producing a "Radio Music Box" for home use. No action is taken on the proposal.[18]

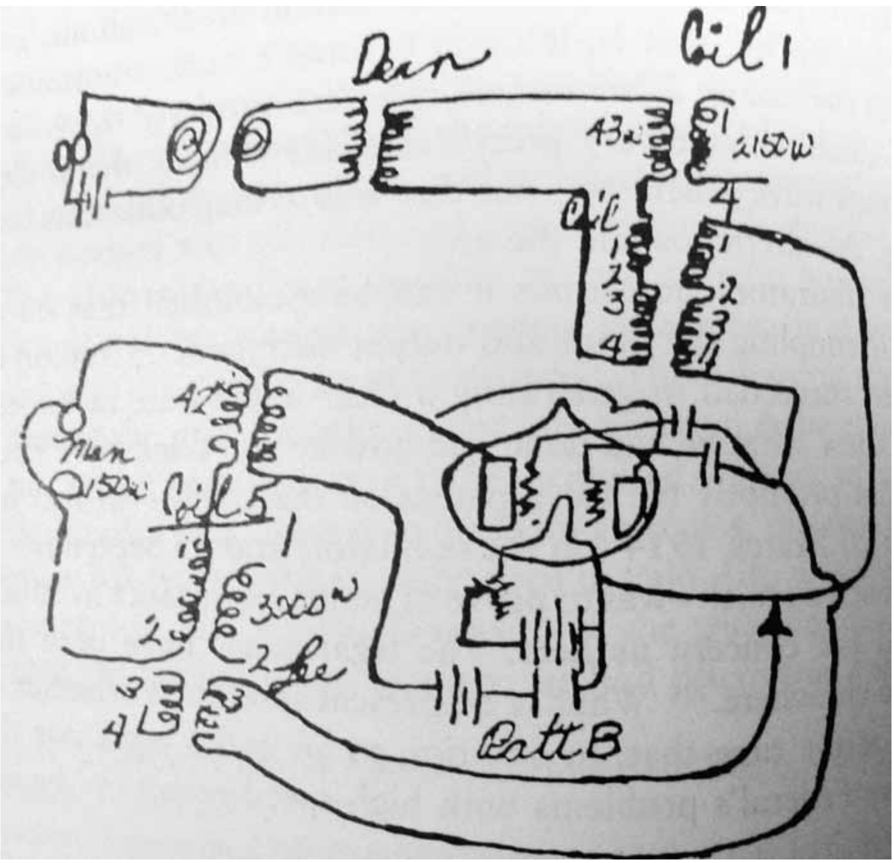


Fig.4. DeForest feedback circuit.

Events of the 1917–1918 War Years

March 1917 Deforest sells all remaining Audion rights to AT&T for $ 250,000.00. He reserves the rights to his own use and sales to amateurs and experimenters. AT&T now has the rights to deForest's feedback and oscillator patent applications and the patents should they become validated.[7]

April 6, 1917 The US enters World War 1 and Armstrong joins the Army. As a captain he is sent to France where he works on problems with military wireless communication. He would later be promoted to the rank of Major and invent the Superheterodyne during his time in France.

April 1917 Legislation is passed pooling all patents for use in the war effort. Anyone working to fill government orders for the war effort could make free use of any patents. Lee deForest and his company become fully engaged in filling government contracts. With all patents available for use, great strides were made by AT&T, General Electric and others in wireless work for the war effort. Improvements were made in vacuum tubes and transmitters.

After the war ends and while Armstrong was still in France, deForest and his attorneys move to have the patent office change the wording of the original description of his invention. This was part of his 1915 application and documentation drawn up by the patent office examiner in 1917. Lee deForest wanted the wording in two counts of his application that read "Means of producing sustained high frequency oscillations" changed. He requested it read "Means of producing sustained electrical oscillations". This request was first denied. The attorneys appealed and an examiner who stated that the difference between high and low frequency isn't clear to him therefore he approved the change. This wording change ignored a major technical difference between low frequency, meaning audio and high frequency, meaning radio frequency. By using the phrase "electrical oscillations", deForest could claim that his invention was to cover all frequencies. Armstrong had a limited time to appeal but in the delay of getting a response back from France, he missed the deadline. The change was made.[19]

If we look back at the 1915 deForest feedback applications he showed three dates of steps toward the complete invention but only one predated Armstrong. This was the squealing August 6, 1912 audio line amplifier for AT&T. This wording change meant that this could also be a radio device as it was noted to make electrical oscillations and he could also claim it was a first step at inventing a feedback circuit. If this argument were accepted, it would put his invention date earlier than Armstrong's.

In 1918 word also reaches Armstrong in France that deForest and others are openly infringing on the regeneration patent and he prepares to finish his work and return to the US.

Events of the Year 1919

September 1919 Major Armstrong returns from his service in France.

November 20, 1919 The U.S. government recognizes that in post war America there is the need for an American operated radio business. RCA is formed with the help of General Electric and the government. American Marconi transfers all assets and operations to RCA.[20]

1919 Marconi paid Armstrong a total of $3,000.00 for regenerative license royalties.[21]

Events of the Year 1920

January 1920 David Sarnoff resubmits his radio music box proposal to RCA chairman Owen D. Young. He includes an optimistic sales projection as he predicts broadcasting and home radio set sales will boom.[22]

April 1920 Armstrong's attorneys suggest a non-exclusive, non-transferable license to permit small companies to use the regenerative circuit for producing receivers for amateur use. Licensing begins and one of the first payments received is from the Clapp-Eastham Company for $ 12.60.[23]

July 1, 1920 The RCA radio group had been formed to bring together major patent holders into a license pool. Negotiations are completed and cross licensing agreements brings AT&T into the radio group. This brings the deForest patents to RCA including the feedback application.

September 1920 Westinghouse declines RCA's initial offer to join the radio group.

October 5, 1920 Westinghouse purchases an option to acquire the Armstrong patent.

November 1920 At this date, 17 companies are licensed to manufacture regenerative receivers for amateur use. Royalties are set to be 5%. Income from royalties begins to grow.[24]

November 4, 1920 Westinghouse exercises their option and Armstrong sells a package of patents to Westinghouse including Regeneration, Superheterodyne and some joint patents with Pupin. Armstrong works with Westinghouse attorneys to bring a suit against deForest Radio & Telegraph Co. They plan to assert the validity of Armstrong's regenerative patent over deForest's infringing claims in the patent office. Armstrong would receive an additional payment from Westinghouse when the regenerative patent challenge is removed.[25]

And with the challenge removed, Westinghouse would be in a stronger bargaining position with RCA and the radio group.

Events of the Year 1921

January 1921 Trial begins in U.S. Federal Court, Southern District of New York before Judge Julius Mayer. Armstrong supported by Westinghouse, spends long hours preparing documentation, building demonstration pieces and testifying in court. In preparing these demonstrations Armstrong invents superregeneration.[26] DeForest's interest is backed by AT&T. From this time on the greatest financial interest is now with the corporations and the personal interest is with the inventors.

April 1921 Armstrong publishes an article "The Regenerative Circuit" in the *Electric Journal Vol. XVIII no. 4.* In this he tells the story of his discovery of the phenomenon of feedback and how through hard work and analysis, he turned this discovery into an invention, the regenerative circuit and oscillating audion circuits.

Events of the Year 1922

March 1922 The trial before Judge Mayer ends in victory for Armstrong. A subsequent appeal before the U.S. Circuit Court of Appeals also finds for Armstrong. DeForest's case had rested on three points. First that the August 1912 notebook entry established his realization of the concept of the feedback and oscillator principles, second that he completed the invention according to notebook entries on April 17, 1913 and third that in October 1913 he put it into practice with an installation for a radio operator friend. The court battles were hard fought. Armstrong's notarized diagram from January 1913 was challenged. Armstrong's witness had died during the war and the notary had died. The notary's widow had to testify to the validity of the signature.[27] Armstrong attacked deForest on all three points. It was claimed that the 1912 circuit could not work, the 1913 circuit was made after Armstrong's demonstrations and the date given for putting a receiver into practice was proven to be wrong. When asked to defend his delay in filing for his patent deForest claims a lack of funds and other pressing work. It has been pointed out that deForest had as many as 30 other patent applications between 1912 and the 1915 application.[28]

The next step after the trial would be for the court to assess damages. After evaluating deForest's financial situation and after many court delays, Westinghouse attorney's recommend that as in many cases Armstrong should waive damages and receive a final decree. Armstrong, with an engineer's view of what is right and wrong, refuses. In his mind there is nothing in between. DeForest is wrong and he must pay.

Fig.5. Armstrong raises a patent number flag visible from deForest's residence.

Armstrong's view of how the legal system should work and in this instance, keeping a legal window open for deForest would allow the battle to continue.

1922 The companies Armstrong licensed to produce amateur regenerative receivers are enjoying the radio boom. Royalty payments now reach as much as $ 10,000.00 per month. David Sarnoff's optimistic prediction for sales of "radio music boxes" exceeds predictions.[23]

The DeForest Radio Telephone and Telegraph Co. purchases the Radio Craft Co. in order to obtain the regenerative license needed to produce a competitive home radio.[29]

June 1922 In an article for Radio Dealer magazine deForest gives credit to the work of other engineers who contributed to the development of radio. He does not include Armstrong on his list.

Events of the Year 1923

1923 Patent Office Tribunals continue investigating interference claims and make no changes during this period. DeForest waits expecting a change from the patent office in response to his change in the wording of his 1915 patent application.

Events of the Years 1924–1925

April 21, 1924 Lee deForest has seen no action taken on the 1914 and 1915 patent applications. With the wording on his patent applications changed, but still getting no response from the patent office, he takes his case to court. With this wording change he will claim priority of the invention. He will ask that the August 6, 1912 notebook entry be his date of invention. DeForest records in his diary, "After 2 weeks more or less awaiting my turn to be witness in the suit to annul the pesky patent of my hated enemy Armstrong. I finally finished my three days on the stand Friday. Time alone will tell the outcome. What joy 'twould be to at last see the patent which has cost me (and the radio public) so much- annihilated and the rude egoist put back where his real achievement belongs." [30]

May 8, 1924 The District of Columbia Court of Appeals, Judge Josiah Van Orsdel, rules for deForest. The ruling states, "We are not here concerned with the question of whether the production of electrical oscillations be of radio or audio frequencies or to what particular use they are put". Judge Orsdel also saw no reason to invalidate Armstrong's patent. Now there are two inventors of the feedback circuit.[31]

May 11, 1924 The New York City News reports on the decision. They state that although deForest Radio Company will net $ 500,000 per year from royalties, deForest himself will only net about $ 15,000 per year since he had sold so much of his interest.[30]

September 2, 1924 After the court ruling the U.S. Patent Office awards deForest patent 1,507,016 and 1,507,017 for the oscillator and feedback circuits. They would expire in 1941.[32]

September 1924 DeForest returns to his work on Phonofilm. (Film sound recording)

Events of the Year 1926

1926 In the Federal District Court in Philadelphia attorneys for deForest move to have Armstrong's patent declared invalid. When Armstrong defends his case, the judge dismisses the two earlier cases in 1922 which found for Armstrong. This is done based on the fact that Armstrong refused to waive damages against deForest and never received a final decree in 1922. With these cases dismissed the decision reverts back to the patent office tribunals decisions. In this decision the court cites the legal precedent of Morgan v. Daniels which ruled that since no new evidence had been presented (the patent battles were now 12 years old) the court would not act in this case. With no new evidence the court will not contravene the decree of an executive department of the government. In this case it means the decision goes back to the patent office decision that allowed deForest to change the wording in his application from high frequency oscillations to electrical oscillations. Since the squealing amplifier in DeForest's August 6, 1912 lab notes are producing an electrical oscillation, then this pre-dates Armstrong's January 31, 1913 notarized diagram. Therefore priority goes to deForest and Armstrong's patent is nullified. DeForest is now the sole inventor of the feedback circuit. [31]

July 29, 1926 After the victory, deForest sends Armstrong a telegram which reads in part "Dear Major, How about again insulting the Franklin Institute with a few characteristic remarks".[33] A short time later, in court in Delaware, Armstrong along with Langmuir and Meissner attempt to have deForest's priority overturned. Again the same precedent of Morgan v. Daniels is cited and judgment is in favor of deForest. With no new evidence the same decision is given by the Third Circuit Court of Appeals. Armstrong's only hope to have the case examined on the technical merits will be to have it heard by the U.S. Supreme Court.

Events of the Year 1927

November 1927 Thanksgiving Day Armstrong has a meeting at the New York law firm of Cravath, Henderson and de Gersdorff. He meets with senior member Fredrick H. Wood and a young lawyer Alfred McCormack. He told them he was ready to take the patent battle to the Supreme Court. McCormack had clerked in the Supreme Court and impressed Armstrong. It was arranged that McCormack's other work would be reassigned and McCormack would prepare the brief. This would be done Armstrong's way. He started a 3 month period of teaching McCormack radio electronics.

Events of the Year 1928

Summer 1928 With Attorney McCormack's electronics training complete, all of the legal work begins to prepare a brief for the Supreme Court's October term.

October 18, 1928 Preparations for the trip to the Supreme Court in Washington run to the last minute. When they miss the last train, Armstrong calls the Pennsylvania Railroad and hires a private train. With a $ 1,200.00 train ticket McCormack, Armstrong and a Westinghouse lawyer arrive on schedule only to find the hearing delayed one day. One of Armstrong's contentions was that the patent office should not have allowed the change in language in deForest's patent application that we saw happen in 1919. If the original wording stands and the deForest notes show to be unworkable at radio frequency then it can be shown that the Armstrong January 31, 1913 date will have priority.[34]

The attorney for deForest and AT&T is former presidential candidate Charles Evans Hughes. He argues that since Armstrong didn't challenge the wording in 1919 that it shouldn't be challenged in 1928. We can recall Armstrong's challenge arrived from France after the deadline. Hughes then argues that since there were no legal errors the ruling of the lower court should stand. In a short time the Court handed down a memorandum opinion which let the deForest decision stand. This was done on legal precedence citing Morgan v. Daniels. The months of work on technical arguments were never considered.[35]

Armstrong has now lost in the highest court in the land. If he is to find a path to another challenge it would have to be through a third party. He would be on his own as no corporation would have any interest in the matter. Until the right situation occurs Armstrong, now truly the lone inventor, waits.

Events of the Year 1929

1929 Before the stock market crash, Armstrong sells a large block of his

Fig.6. Armstrong visits his old radio room where he built his first regenerative receiver.

RCA stock for $ 114.00 per share. These are funds he would need for the legal battles still ahead.

Events of the Years 1930–1933

1930 Armstrong and his supporters keep watch for the right opportunity to bring the case back to court. Their plan is to find a case where a company is being charged with infringing on the feedback patent. Armstrong would then step in and back the defendants claiming that the deForest patent should be declared invalid on its merits.

1931, 1932 A small New York manufacturer, Radio Engineering Laboratories (REL), was selling a small transmitter kit without an RCA license. RCA brought a suit against REL. Armstrong through an intermediary obtained an option to purchase 51% of REL and pledged to back REL in the suit. In the Federal Court of the Eastern District of New York the case was presented before Judge Marcus B. Campbell. After hearing all of the testimony he ruled for deForest stating that he saw no material difference from that presented in earlier hearings. [36]

1933 Armstrong did not hesitate in filing an appeal with the Court of Appeals for the Second Circuit. A three judge board found for Armstrong. In their statements the court pointed out the inconsistency that if deForest discovered the valuable principle of feedback in 1912, why did he not apply for the patent until 1915 after Armstrong's invention had become well known.

Many congratulations came from the professional community. They included Cyril F. Elwell, deForest's superior at Federal Telegraph when he produced the August 1912 sketch, also from W.A. Kintner, the patent office examiner and Irving Langmuir, one of the early contenders for the feedback patent. Also many letters came from colleagues at RCA. They included two of special interest. First from Manton Davis, general counsel for RCA, congratulating Armstrong in a hand written personal letter. And second a telegram from David Sarnoff offering his heartiest personal congratulations.[37]

September 1, 1933 One day after his personal congratulations RCA issues a press release. It states that the recent court decision is in conflict with earlier decisions and they expect the matter will be settled by the Supreme Court. Not mentioned in the press release is the incentive of 10 extra years of royalties if the decision is reversed.[37]

Events of the Year 1934

May 2, 1934 Hearings before the Supreme Court begin. DeForest is represented by Sam Darby, his personal attorney, as well as lawyers for RCA and AT&T. William H. Davis represents REL.

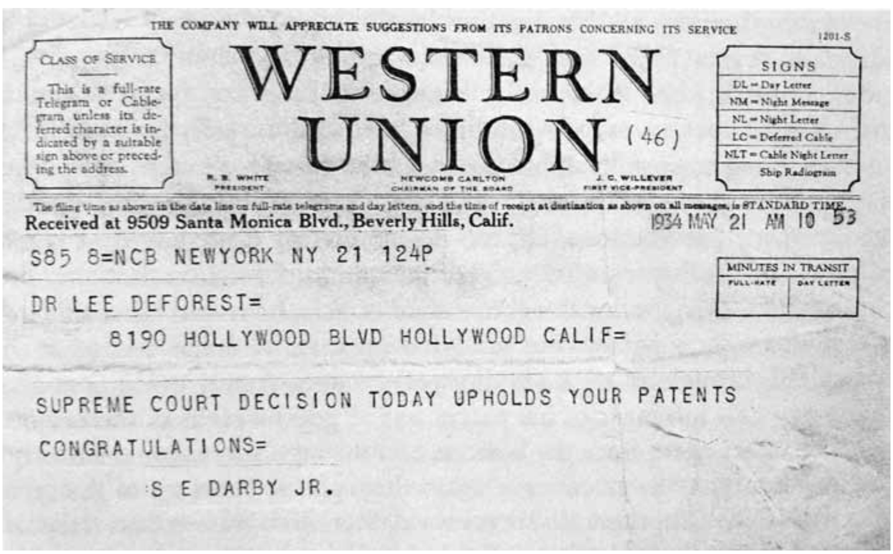
May 21, 1934 US Supreme Court Decision favors deForest. The court's decision is presented by Justice Benjamin

Cordozo. He presents the history of the case as well as again citing the precedent of Morgan v. Daniels. He also rules on the technical merits of the case. Cardozo and the court accepts the technical facts as presented by deForest. He tries to explain that the 1912 deForest diagram meets the requirements of a radio device. Radio people immediately see this decision as a huge technical error. DeForest's attorney, Sam Darby, sends deForest a telegram with the results.

Prominent scientists and engineers, including Michael Pupin and Louis Alan Hazeltine, the Neutrodyne inventor, begin a public letter writing campaign describing the court decision as a terrific blunder. A request is made to the court to review this information. It only results in small changes and the ruling stands.[38]

May 29, 1934 The Institute of Radio Engineers holds its ninth annual convention in Philadelphia. Armstrong informs the Institute that he plans to return its Medal of Honor which had been presented to Armstrong in 1918 for his work on the regenerative circuit. Armstrong is prepared to deliver the following speech:

"It is a long time since I have attended a gathering of the engineering and scientific world-a world in which I am at home-one in which men deal with realities and where truth is, in fact, the goal. For the past ten years I have been an exile from this world and an explorer in another-a world where men substitute words for realities and then talk about the words. Truth in that world seems merely to be the avowed object. Now I undertook to reconcile the objects of these two worlds and


THE COMPANY WILL APPRECIATE SUGGESTIONS FROM ITS PATRONS CONCERNING ITS SERVICE

CLASS OF SERVICE
This is a full-rate Telegram or Cablegram unless its deferred character is indicated by a suitable sign above or preceding the address.

WESTERN UNION (46)

R. B. WHITE, PRESIDENT — NEWCOMB CARLTON, CHAIRMAN OF THE BOARD — J. C. WILLEVER, FIRST VICE-PRESIDENT

SIGNS
DL = Day Letter
NM = Night Message
NL = Night Letter
LC = Deferred Cable
NLT = Cable Night Letter
Ship Radiogram

1201-S

The filing time as shown in the date line on full-rate telegrams and day letters, and the time of receipt at destination as shown on all messages, is STANDARD TIME.

Received at 9509 Santa Monica Blvd., Beverly Hills, Calif. 1934 MAY 21 AM 10 53

S85 8=NCB NEWYORK NY 21 124P

MINUTES IN TRANSIT — FULL-RATE — DAY LETTER

DR LEE DEFOREST=
8190 HOLLYWOOD BLVD HOLLYWOOD CALIF=

SUPREME COURT DECISION TODAY UPHOLDS YOUR PATENTS
CONGRATULATIONS=
S E DARBY JR.

Fig.7. Telegram from Attorney Sam Darby congratulating deForest on his second Supreme Court victory.

for a time I believed that that could be accomplished. Perhaps I still believe it—or perhaps it is all a dream…"

The speech was never delivered. The president of the Institute addressed Armstrong in front of the hundreds of attendees. He stated it was the unanimous opinion of the board of directors, including those who associated with RCA and AT&T that the Institute reaffirms the Medal of Honor for the same reasons it was presented in 1918. From this point onward Armstrong's recognition for his achievements with the regenerative circuit would only come from his peers.[39]

After the 1934 Decision

1935 Earlier David Sarnoff had deferred from having RCA give Armstrong any help in the patent battle. Yet at a stockholders meeting in 1935 when Sarnoff's leadership is challenged, Armstrong rises to defend Sarnoff as the man responsible for keeping RCA together through the hard times of the depression.

September 22, 1939 This day is Lee deForest Day at the 1939 World's Fair. The legend of "The Father of Radio" is perpetuated.

May 8, 1941 The deForest feedback and oscillator patents expire.

December 26, 1943 Armstrong testifies in a Congressional Hearing on the radio business. He lists inventor of regeneration as a qualification. This triggers a renewed campaign by deForest to set the record straight.

January 31, 1954 Carrying the scars of this battle and a lifetime of other battles, Edwin Howard Armstrong dies in a suicide.

June 30, 1961 Mostly bed ridden after a heart attack in 1958, Lee DeForest passes at age 87.

Some Conclusions

Many years ago when I began collecting early radios, I would ask other collectors when they thought wireless became radio. There were various opinions. In researching this article I believe I have found an answer. When the inventions of these two men became ready for manufacturing it enabled home radio broadcasting to begin. That to me marks the time that Armstrong and deForest, more than any others, converted wireless into radio.

Both of these men compiled an incredible list of accomplishments in their careers. Both received honors and recognition from their colleagues and the public. Both made and lost fortunes they had been paid for their inventions. Both won and lost in the legal system.

Their personalities are the products of many other factors in their lives as well as this battle over regeneration. And this battle didn't end with the Supreme Court. For the rest of his life Armstrong would always feel he was the true inventor. He will have a friend join the deForest Pioneers to get reports on their meetings and he would hire a news clipping service to keep track of deForest's activities. DeForest would occupy the rest of his life not only justifying

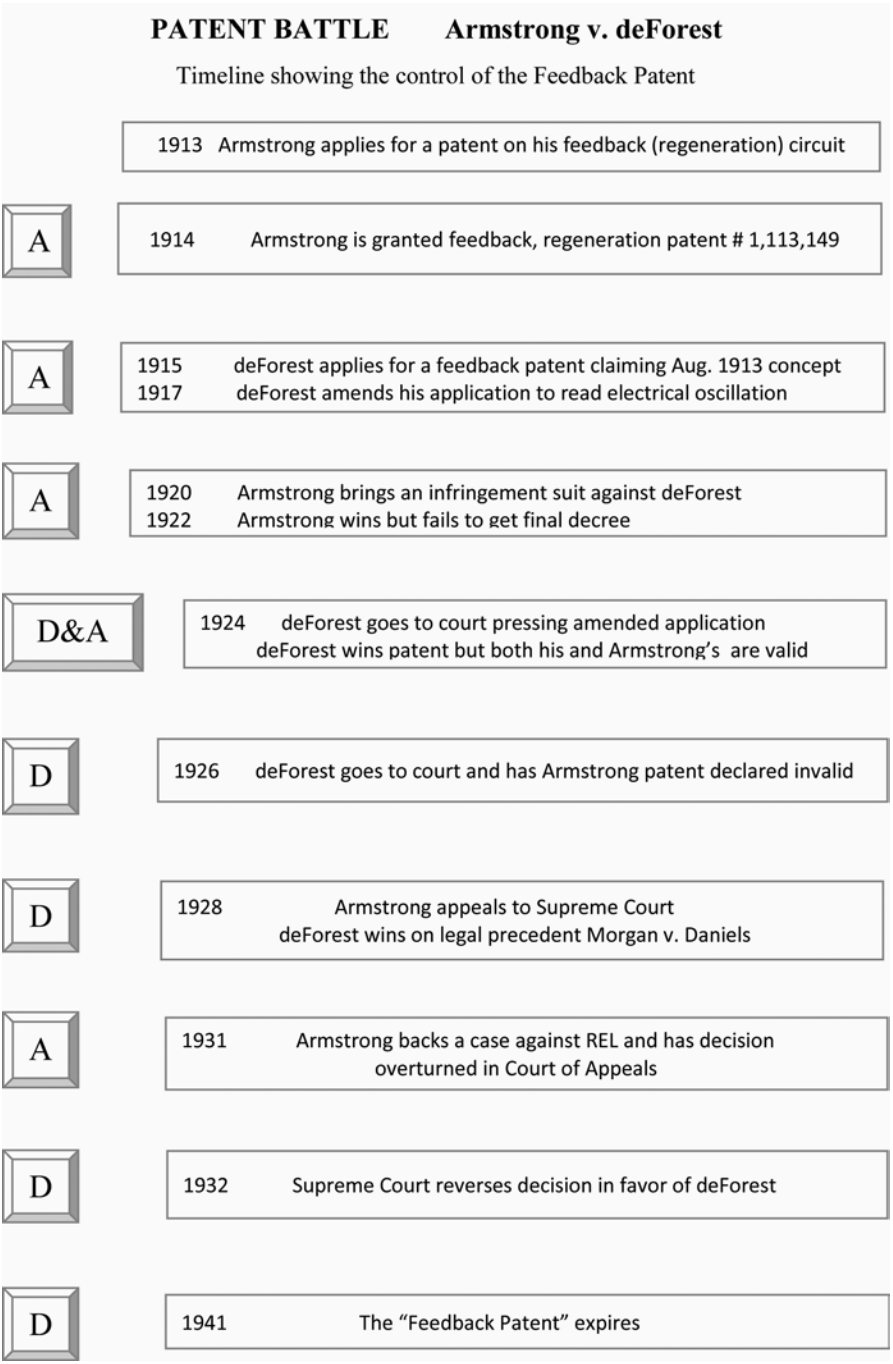


Fig.8. Timeline of dominance of Armstrong versus deForest.

his claim to regeneration but also looking to challenge most of Armstrong's accomplishments. For us to look back on this story 100 years later there is one common denominator that would make an observer pick one side or the other. The matter rests on determining at what point you believe a discovery or creation has become an invention. We've seen that what the laws and the courts may decide could have little to do with what the inventors and their contemporaries may believe. Does a person who notes the result of an experiment that he doesn't immediately understand or apply until some later date have an invention on the earlier date? Does an invention occur when a discovery is made with a basic understanding of the result and a reduction to practice? Certainly deForest and Armstrong had opposite opinions of this argument.

We can also see an explanation for their different viewpoints. Although they were born only 17 years apart they are from different generations. Lee deForest was a 19th century inventor. He came to enter the technology world during a rough and tumble time during America's rapid growth spurt. Inventing was an empirical process as the science explaining the inventions was lagging behind. The business practices of the time brought investors to these inventors. Investors big and small came hoping to strike it rich by investing in companies that rarely succeeded.

The supreme empirical inventor of the time was Thomas Edison. When asked how he knew the carbon filament would work in a light bulb he famously answered that he knew by trying everything else first. Effort to understand the science first and invent second was yet to come. It can be easy to see that if deForest's laboratory experiments pointed to ions making the audion work then he would believe it. He knew of no science that would tell him otherwise. DeForest, an admirer of Edison, would be the empirical inventor "cutting and trying" and keeping good notes.

Armstrong was a 20th century inventor. Physics was beginning to explain the electron and electromagnetic phenomenon. Just as Edison's empirical inventing gave way to General Electric's scientific research, so did inventing in Armstrong's lab at Columbia University give way to corporate research. Armstrong described the invention of the feedback circuit as discovering a scientific phenomenon followed by experiments to explain what has occurred. Once it is explained seeing an application for the discovery and making use of it becomes the invention.

One can see how both men believed they were right and as the battle wore on, each man's position would harden. But in the end both men were pawns to big corporations. They may have had friends in corporations but they could not influence the decisions of corporations. Both men would remain bitter toward the other for the rest of their lives. After Armstrong's death radio engineer Carl Dreher would write an article for the April 1956 issue of Harper's magazine. It was entitled "E.H. Armstrong, the Hero as Inventor". It would praise Armstrong's accomplishments including the invention of regeneration. DeForest could not restrain himself from writing to Dreher to set the record straight by attempting to discredit most of Armstrong's work. Dreher's reply may best describe the sad ending to the long and bitter battle for the feedback patent.

He wrote to deForest, "You are the legal inventor. But every engineering opinion was overwhelmingly against you while the controversy raged, and insofar as I had a chance to sample it while researching this article, it is against you still. Among the older men, that is. The younger ones don't give a damn." [40]

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Photo Credits

Figs.1, 7. Mike Adams, "Lee deForest"

Fig.2. Broadcast vol. 1, no. 1, 1922 via Wikipedia

Figs.3, 6. Houck Collection via E.H. Armstrong website

Fig.5. Radio Club of America, "Legacies of Edwin Howard Armstrong"

About the Author

After leaving Stevens Institute, **Mike Molnar** decided to fulfill his long time ambition to start his own company. Against the advice of many he started a TV and Electronics business. The many were right and the business soon ended. Undaunted Mike started another company, Diagnostic Services Inc., in 1983 working with gamma cameras used in nuclear medicine. Still a successful business today Mike designs and builds nuclear medicine systems specifically for veterinary use in both small animal and equine hospitals and universities.

Mike is a long time AWA member and his interest in old radio, television and electronics also continues. His large collection is still growing in his home and available for many to see on the electronicfossil website. With the help of his patient wife Pam, Mike serves as caretaker to the fossils.

Author Mike Molnar uncovering yet another artifact for www.electronic fossil.com.

Part III: Otis B. Moorhead and the Vacuum-Tube Tangle

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Abstract

The vacuum-tube tangle refers to the tangled web of conflicting patent rights associated with the Fleming valve and the DeForest audion that resulted in numerous imbroglios among RCA/Marconi, DeForest, Western Electric/AT&T, Elmer Cunningham,[1] Otis B. Moorhead, and Elman E. Myers.[2] This article dealing with Otis Moorhead, his companies and associated sales agencies draws on original sources including thousands of pages of original documents from Gerald Tyne's personal library dealing with the vacuum tube tangle, 4,000 pages of testimony in eight volumes taken from principals during the FTC hearings on the RCA monopoly, and many other contemporaneous documents.

This article greatly expands the knowledge base of Moorhead's involvement in the tube tangle and provides explanations for several enduring enigmas. What is the "De Forest 20 Audion Detector" that appeared only once in an ad placed by A-P Radio Supplies Co. and never again? Why did RCA allow Moorhead to sell vacuum tubes for two years after cancelling the three-party agreements that allowed Moorhead to legally manufacture tubes before filing suit? Who actually made the DeForest Singer type tube with the Shaw base sold by DeForest in 1920? Who actually made the A-P solenoid tube?

Overview

Unlike Cunningham, Otis Moorhead manufactured vacuum tubes for the U.S. and British Governments during WWI. Moorhead gained notoriety as a quasi-legitimate tube manufacturer after the war by producing a variety of vacuum tubes, most notably a line of tubes based on the Type SE-1444 tube manufactured for the U.S. Navy under patent protection during the war. To satisfy the patent rights of all parties after the war, DeForest, Marconi, and Moorhead entered into three agreements dated June 6, 1919 whereby Marconi licensed Moorhead to manufacture tubes under the Fleming patent, Moorhead became an employee of the DeForest Radio Telephone and Telegraph Co. as the sole manufacturing agent for DeForest, and Marconi became the sole distributor for the tubes made by Moorhead. These complementary agreements were created in an attempt to satisfy the terms of DeForest's assignment of his audion patents to AT&T whereby DeForest had retained limited rights to manufacture and market three-element tubes to radio amateurs. Marconi advertised these tubes for sale under these agreements from July of 1919 until shortly before they were cancelled effective July 30, 1920 at the direction of RCA, who became successor to American Marconi as of Nov. 20, 1919. RCA entered into cross-licensing agreements with AT&T and General Electric (GE) in June 1920 that permitted GE to manufacture tubes under the DeForest patents for RCA, who in turn sold them to amateurs and experimenters.

Although the three-party agreements were cancelled effective July 30, 1920, Moorhead Laboratories continued to manufacture and sell tubes to amateurs and experimenters without a valid license under the direction of Henry M. Shaw, who gained controlling interest in Moorhead Labs circa April 1, 1920. RCA was reluctant to prosecute Shaw and Moorhead Labs for infringement, in part because GE was unable to produce tubes for sale by RCA in July of 1920 as originally planned. As a result, RCA agreed to license Moorhead under both the Fleming and DeForest patents to sell an additional 35,000 tubes provided they agreed to cease operations after these tubes were sold, thus giving Moorhead Labs a quasi-legitimate status that lingered on and on. The ensuing entanglement that took place over a two-year period produced volumes of correspondence, resulted in a number of written and oral agreements between and among the various parties, and provoked two lawsuits.

RCA sued Moorhead Labs and its principals alleging infringement of the Fleming patent on April 24, 1922. AT&T joined in the fray within two weeks by also suing Moorhead Labs and its principals alleging infringement of the DeForest patents on May 9, 1922. Shortly thereafter, Moorhead Labs voluntarily ceased operations, but Otis Moorhead then created the Universal Radio Improvement Co. circa November 1922 with a new factory in Alameda, CA. However, he died on January 31, 1923 before the factory was able to produce tubes in quantity, and the charter for Moorhead Labs was then allowed to lapse in January 1924, thus ending the colorful saga of Moorhead Laboratories. The assets of Moorhead Laboratories were sold to a new company in 1924, A-P Radio Laboratories, who manufactured tubes for another year before voluntarily ceasing operations in mid-1925.

In the ten-year period between 1915 and 1925, Otis Moorhead spawned nine different companies, four of which were tube manufacturers and the other five were sales agencies for Moorhead Labs. The evolution of these companies and the relationships of the sales agencies to Moorhead Labs are shown in Fig. 1. The flow chart also serves as a roadmap for the remainder of the article by identifying the companies, the principals

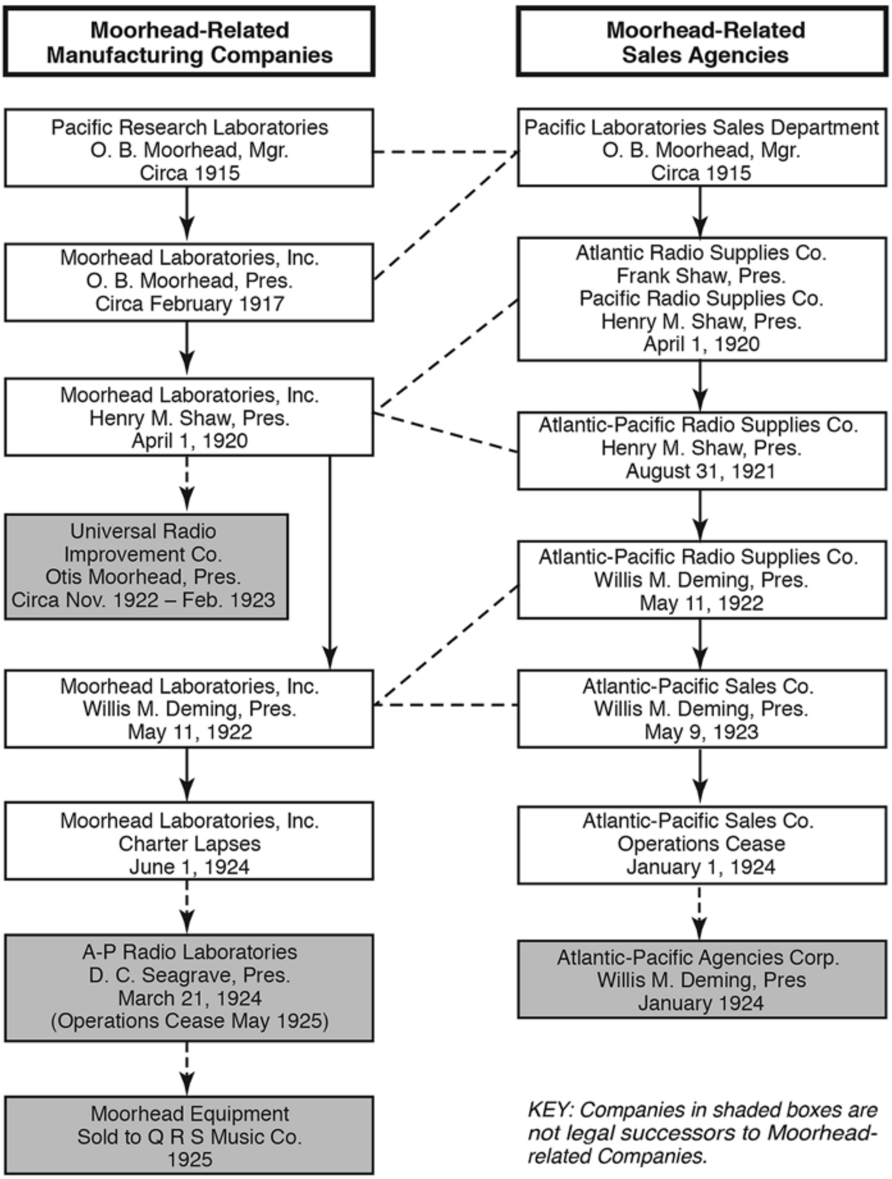


Fig.1. The evolution of Moorhead-related tube manufacturing companies appears in the left column, the evolution of Moorhead-related sales agencies that represented these tube companies appears in the right column, and the relationships between the two are indicated by the respective dashed lines that connect them; companies that were not legal successors to Moorhead-related Companies are indicated by shaded boxes.

associated with each, and the dates they were created and ceased operations. The four companies in the shaded boxes were created as a result of actions by the principals of Moorhead Labs but were not legal successors to either Moorhead Labs or the various Atlantic and Pacific sales agencies.

The War Years

Moorhead Labs was selected to manufacture tubes during WWI for the U.S. Navy and British Government under U.S. Government protection from patent infringement litigation. Several substantial wartime contracts provided Moorhead with the financial resources to outfit a tube factory in an existing three-story brick building with a basement at 638-640 Mission Street in San Francisco (see Fig. 2).[3] A view of the Stem Manufacturing Department in Fig. 3 reveals rudimentary production equipment with heavy reliance on manual labor.[4] The executive offices of the Company were situated in the Call Building (also known as the Spreckels Building) located just blocks from the factory at Third and Market Streets (see Fig. 4).

Moorhead was able to incorporate a number of improvements in tube design and construction techniques developed during the war in the three tube types he made for the U.S. and British governments. These tubes were the Navy Type SE-1444 receiving audion (see Fig. 5), British Type R receiving valve (see Fig. 6), and British Type B transmitting valve (see Fig. 7)—all of which had a sufficiently hard vacuum that the residual gas did not affect tube performance. These three tube types were described in a paper and a speech delivered to the San Francisco Section of the IRE on Nov. 14, 1919 by Otis Moorhead and E. C. Lange, Chief

Fig.2. Otis Moorhead outfitted this existing building at 638-640 Mission Street during the war as his tube factory. (*Moorhead and His Valve*, Aug. 1919; courtesy of Stew Oliver)

Fig.3. The Stem Manufacturing Dept. in the Moorhead Laboratories tube factory consisted of rudimentary production equipment with heavy reliance on manual labor. (*Moorhead and His Valve*, Aug. 1919; courtesy of Stew Oliver)

Engineer of Moorhead Laboratories.[5] These tubes are also described by the late Bill Condon with accompanying photographs in articles appearing in the *Tube Collector* and on his website, both of which are entitled "Moorhead and His Tubes."[6] Based on serial number data contributed by the tube collecting community, Bill Condon estimated that Moorhead made about 20,000 Type B and 45,000 Type R tubes for the British Government and another 25,000

Fig.4. The executive offices of Moorhead Laboratories were located in the Call Building—also known as the Spreckels Building—which was located several blocks from the factory at Third and Market Streets.

Fig.5. All of the tubes manufactured by Moorhead for sale by Marconi were derivatives of the SE-1444 developed for the Navy during the war.

Fig.6. The British government contracted with Moorhead during the war to manufacture this Type R receiving tube, which was fashioned after the French Type TM valve but with a vertical plate structure. (Joe Knight collection)

Fig.7. Moorhead manufactured the British Type B transmitting tube, which was similar to the Type R tube but with a horizontal plate that had a grid of 22 turns—twice the number used in the Type R. (Stew Oliver Collection)

SE-1444 tubes for the U.S. Navy during WWI.

Condon reported that one sample of a B tube has been observed with a paper label stating the tube was made under the Fleming license. That license (discussed later in this paper) was granted under an agreement between the Moorhead and Marconi Companies dated Nov. 4, 1918, so that at least some of the B tubes must have been manufactured after the armistice. That license agreement also specified that Moorhead had a contract with "His Britannic Majesties Government" (cited as U.S. 6754-MM 263) for 75,000 tubes, and that Moorhead would pay a royalty on each tube made under this contract. The clear implication was that a number of tubes would be made for the British Government after Nov. 4 1918. Because the estimated number of Type B and R tubes fall far short of the 75,000 tubes identified in the license agreement, it is likely that a significant number of the remaining tubes manufactured under this contract were the VT-32 (see Appendix B), a variant of the Type B tube that Condon stated were made without serial numbers in large quantities.

All three tubes were a significant departure from the Electron Relay tube made by Moorhead for sale to amateurs before the war, most notably in the degree of vacuum. The Electron Relay tube had trace gases that permitted "gas action," as Moorhead put it, which resulted in a more sensitive detector than the hard tubes developed during the war. One might ask, "If the soft tubes were more sensitive detectors than hard tubes, why would the military buy hard tubes to the virtual exclusion of soft tubes?" Captain Ralph Bown, U.S. Army Signal Corps, answered this crucial question in a paper published after the war:[7] "Specifically, the tubes must show uniform operation over ranges of 20 per cent variation of filament and plate voltages since no rheostats or potentiometers were to be allowed and the tubes must automatically adjust themselves over the range of voltage (initial to discharge) impressed by the fixed storage batteries and dry batteries or dynamotors used in the circuits. This requirement was a radical departure from practice with ordinary vacuum tubes, which depended for proper operation upon careful adjustments of filament and plate voltages. It required a combination of inherent stability, uniformity and flexibility previously unknown in radio practice. All tubes were to possess a high degree of electrical and mechanical ruggedness and a reasonably long useful life over which they would maintain their initial characteristics without appreciable change. They must be pumped to have and retain a high vacuum so as to be free of any appreciable effects due to ionization of residual gas."

While the military had valid reasons for purchasing hard tubes, it was the soft tubes that were in demand by amateur radio enthusiasts who enjoyed the thrill of DXing—that is, receiving signals from ever-more-distant stations. The longest distances were received using soft tubes with a trace of gas, which when operated at the most sensitive point on the characteristic I-V curve, proved to be consistently more sensitive detectors than the hard tubes. It made no difference to the amateurs that the tubes did not exhibit uniform operation at standard settings or that it was difficult to find and maintain the "sweet spot" on the characteristic curve—it only mattered that they were able to obtain longer ranges. The soft tubes would be in demand by amateur radio enthusiasts after the war, despite promotion of hard tubes by military and civilian interests.

The Moorhead/Marconi/DeForest Agreements

Although Moorhead Labs had been manufacturing tubes for the U.S. and other allies during WWI, it was on the verge of bankruptcy at the time of the armistice. Otis Moorhead described the debt as being "considerably over $100,000, without assets or credit of any kind except Mr. Moorhead's brain and integrity…"[8] Worse yet, with the wartime patent protection afforded by the Government expiring, Moorhead Labs could not continue to manufacture and market tubes without facing the prospect of protracted and costly litigation with both the Marconi and DeForest Companies. Moorhead blamed the poor financial condition of the Company on his business associates, claiming he had "devoted himself strictly and entirely to the manufacturing or production department of the corporation."[9] Moorhead and his attorney, J. Henry Denning, took charge of the business and commercial affairs effective Nov. 1, 1918 to correct the situation. Denning, a Seattle attorney whose firm incorporated Moorhead Laboratories in the state of Washington in 1917, became Secretary of the Company.

By September of 1919, less than a year later, Moorhead claimed that much of the debt had been erased, and that the company was in much better financial shape. To the extent the financial condition of the Company had improved, the credit was undoubtedly due more to the efforts of Randall M. Keator, Sales Manager for Moorhead Labs, than to Moorhead and Denning. According to Keator's testimony at the FTC hearings, he was responsible for putting together agreements between Moorhead Labs, Marconi and the DeForest Company whereby Moorhead was licensed to manufacture and sell tubes to DeForest, who in turn would sell them to Marconi, who in turn acted as the sole distributor of these tubes for DeForest. The resulting sale of these tubes would have provided the capital needed to improve the Company's financial condition.

Keator testified that he made the deal himself by negotiating directly with Dr. DeForest for the DeForest Company and with Mr. Sarnoff for the Marconi Company:[10] "I saw an opportunity of getting the two companies together, while they would not talk to each other, by getting the third company to make the tubes for them, and that was consummated in this way: The DeForest Company under its reserved rights in 1917 [in the assignment of DeForest patents to AT&T] had reserved the right under those patents to make tubes for certain specific purposes, so the Moorhead Company was to make the tubes for the DeForest Company and put their name on them, and in that way secure a license, at least to manufacture them from the DeForest Company. The Marconi Company of America was made exclusive distributor for those tubes in the United States, which were sold to them by the DeForest Company, and there was also given a license under the Fleming patent to the Moorhead Company, in order that the Moorhead Company could make the tubes."

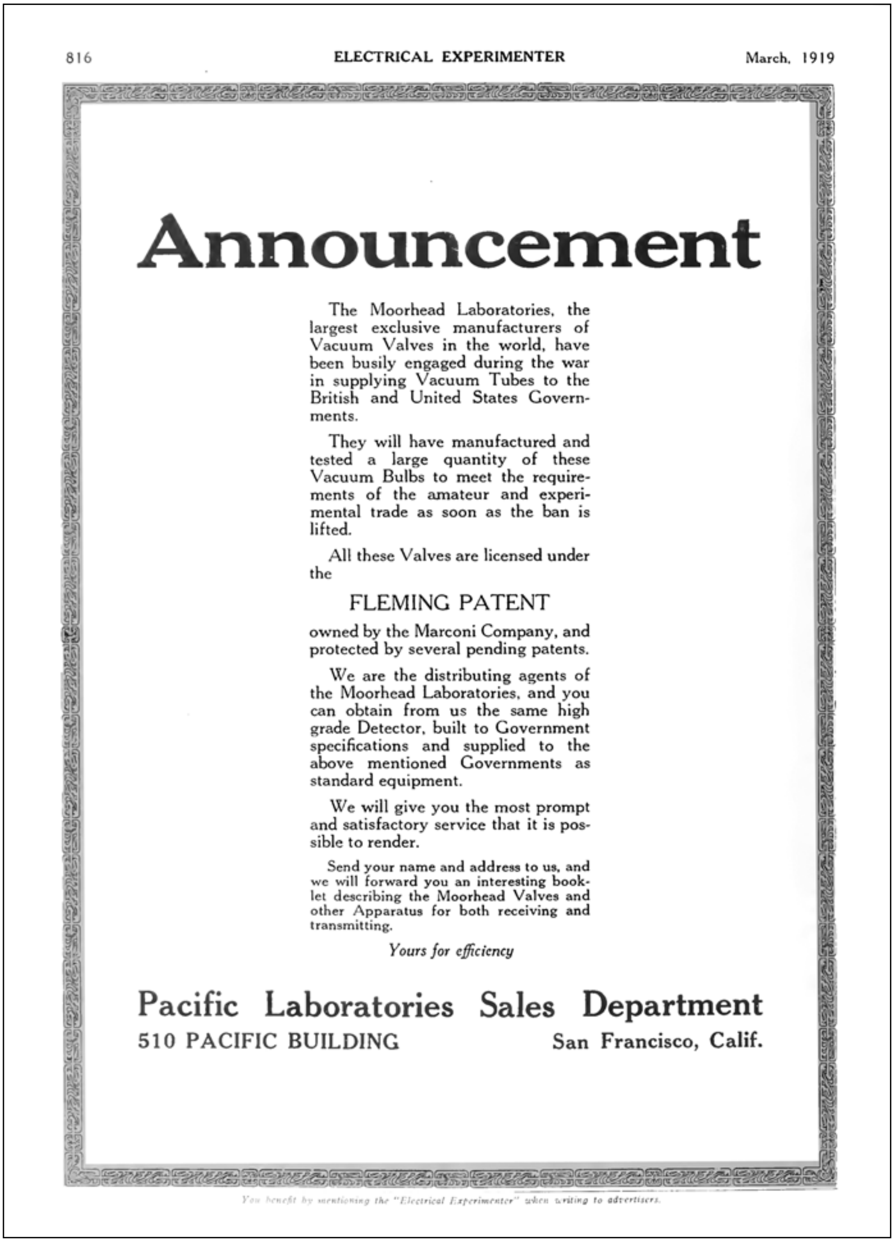
While Keator's testimony made it sound like the agreements were straightforward and made rather quickly, it was actually a tortuous affair that took place over seven months requiring seven different agreements—four of which were cancelled and replaced by three others (see Table 1). The first of these agreements was dated Nov. 30, 1918, less than three weeks after the armistice.[11] It was a relatively straightforward agreement in which the Marconi Company licensed the Moorhead Company under the Fleming patent to manufacture its tubes. What is most interesting about this licensing agreement is the fact that Marconi did not seek the right to sell tubes, nor was there any requirement that the Marconi name be used in branding or naming of the tube. It is clear that at this time Marconi had no interest in participating in the sale or distribution of Moorhead vacuum tubes.

Apparently Keator did not immediately approach DeForest for a license as his testimony implied, because four months later in March 1918 Moorhead began advertising tubes for sale to the public under a Fleming patent license, but without any mention of a DeForest license. The ad reproduced here as Fig. 8, which references only the Fleming patent, was placed by the Pacific Laboratories Sales Department as the distributing agent of Moorhead Laboratories. It should be noted that the ad did not specifically feature or picture vacuum tubes; instead it referred to

Agreement	Date	Type	Cancelled
Moorhead[1]/Marconi	Nov. 30, 1918	Licensing	Apr. 30, 1919
Moorhead/DeForest	Apr. 30, 1919	Licensing	June 6, 1919
Moorhead[2]/Marconi	Apr. 30, 1919	Licensing	June 6, 1919
Moorhead[2]/Marconi	Apr. 30, 1919	Agency	June 6, 1919
Moorhead[2]/Marconi	June 6, 1919	Licensing	July 30, 1920
Moorhead[2]/DeForest	June 6, 1919	Mfg Cont	July 30, 1920
Marconi/DeForest	June 6, 1919	Agency	July 30, 1920

[1]Moorhead, Inc. [2]Moorhead, Inc. & O. B. Moorhead

Table 1: Summary of Three-Party Agreements



816 ELECTRICAL EXPERIMENTER March, 1919

Announcement

The Moorhead Laboratories, the largest exclusive manufacturers of Vacuum Valves in the world, have been busily engaged during the war in supplying Vacuum Tubes to the British and United States Governments.

They will have manufactured and tested a large quantity of these Vacuum Bulbs to meet the requirements of the amateur and experimental trade as soon as the ban is lifted.

All these Valves are licensed under the

FLEMING PATENT

owned by the Marconi Company, and protected by several pending patents.

We are the distributing agents of the Moorhead Laboratories, and you can obtain from us the same high grade Detector, built to Government specifications and supplied to the above mentioned Governments as standard equipment.

We will give you the most prompt and satisfactory service that it is possible to render.

Send your name and address to us, and we will forward you an interesting booklet describing the Moorhead Valves and other Apparatus for both receiving and transmitting.

Yours for efficiency

Pacific Laboratories Sales Department

510 PACIFIC BUILDING San Francisco, Calif.

You benefit by mentioning the "Electrical Experimenter" when writing to advertisers.

Fig.8. This Moorhead ad appearing in the March 1919 *Electrical Experimenter* announced the sale of tubes licensed by Marconi under the Fleming patent for use in both receiving and transmitting.

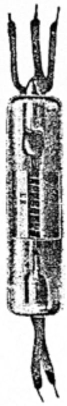
unspecified vacuum bulbs it developed during the war, and offered "the same high grade Detector, built to Government specifications..." It also offered to send upon request "an interesting booklet describing the Moorhead Valves and other Apparatus for both receiving and transmitting."

While no such sales booklet, per se, could be found, a Moorhead price sheet was found in Bill Condon's papers describing three tubes sold to the British and American governments during the war plus a fourth tube, the tubular Electron Relay that Moorhead sold before the war (see Fig. 9). This price sheet mimics the above-referenced ad in two relevant details—both state the tubes are licensed under the Fleming patent without reference to the DeForest patents, and both state the tubes are offered by the Pacific Laboratories Sales Department. While the price sheet is not dated, it was obviously issued sometime after Moorhead Labs was licensed under the Fleming patent on Nov. 30, 1918, and sometime before the first three-party agreements were signed on Apr. 30, 1919 that gave Moorhead a license under the DeForest patent. The ad appearing in the March 1919 issue of the *Electrical Experimenter* fits neatly within this time frame. Thus, one might conclude this price sheet was somehow related to the ad.

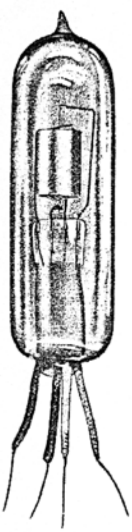
Returning to Keator's story, he approached the DeForest company sometime after he received a license under the Fleming patent dated Nov. 30, 1918 and negotiated an agreement dated April 30, 1919, which was purported to be a license under the DeForest audion patents. It was actually an arrangement whereby DeForest agreed he would not sue Moorhead for future infringements in return for a one-time payment for past infringements and royalty payments for tubes produced in the future. DeForest could not legally provide an outright license like the Marconi license because he was barred from doing so by the terms of his 1917 patent assignment to AT&T. This agreement with Moorhead was the model for two similar agreements that DeForest would sign with Cunningham and Radio Lamp Corporation later in November of 1919.[12] While the agreement specified that DeForest would not bring suit in the future in return for ongoing royalty payments, it was silent about AT&T's right to bring suits for future infringements.

Perhaps the most interesting aspect of this arrangement was the fact that DeForest filed a suit against Moorhead in Federal Court in San Francisco for infringing his audion patents on April 29, 1919, just one day before the agreement with Moorhead was signed.[13] Given that Moorhead was about to sign this agreement with DeForest, legal action by DeForest on the eve of its signing would seem to be unnecessary, if not downright counterproductive. However, the language in the agreement assigning DeForest's audion patents to AT&T specified that either AT&T or DeForest could bring suit against infringers, and that the party who brought suit would retain the proceeds of the suit, if any. By filing this

RELAY
(½ Size)



TYPE R
(Full Size)



MOORHEAD
VACUUM VALVES
FOR
WIRELESS TELEGRAPHY and TELEPHONY

RELAY, Price $5.50

This valve needs no introduction, as it has been used by amateurs and experimenters for over five years. It is a familiar aluminum plate, copper grid, and double filament device operating on 20 to 45 volts plate battery and 4 volts filament battery. It can be used in combination as an amplifier, detector, and oscillator for receiving damped and undamped signals. It carries a guaranteed life of 700 hours. This bulb has been greatly improved during the war and is especially designed for the beginner and experimenter, requiring little adjustment or attention. The recent long-distance records made by the Federal Telegraph Company from Sydney, Australia, to South San Francisco in daylight, a distance of 6000 miles, were accomplished by the use of this valve.

TYPE R, Price $5.00

This valve is built entirely of pure nickel and is the same construction as the valve designed by the British Government for the reception of damped and undamped signals. It requires a plate voltage between 15 and 40 volts operating on a 4 to 6 volt filament battery. It contains a single filament of pure crimped tungsten and is guaranteed for 800 hours life. It has been especially designed for the more advanced experimenter and requires careful adjustment on A and B battery. However, phenomenal results can be obtained with its use. Thousands of these have been built for the British Government and used during the war in all branches of radio communication.

TYPE RH, Price $5.50

This valve is similar to Type R, except that it is evacuated so that any voltage from 50 to 400 on the plate may be used, thus making it especially desirable as an oscillator and amplifier. It can be used as a generator for undamped oscillations for radio telephony and telegraphy. Using the telephone circuit which we will furnish with each valve, a radiation of five-tenths to one ampere may be obtained, and official government tests both by the British and American Governments have proven this amount of power to be sufficient to communicate 120 miles in day time. There are no critical adjustments on this valve, and it may be operated by anyone without trouble. This type has been used in all aeroplane radio sets, and is extremely rigid and long lived.

TYPE B, Price $6.50

Type B is primarily designed for transmitting and is made in accordance with the latest discoveries relating to vacuum valve transmitting sets, although very good results are obtained by using it as a receiver. Using the circuits furnished with this bulb, sufficient radiation is obtained when 500 volts are applied to the plate to cover a distance of 200 miles, daylight, either telephone or telegraph. This bulb is exactly the same as those being furnished the United States Navy at the present time.

YOUR MONEY ENTITLES YOU TO A GENUINE MOORHEAD VACUUM VALVE.
BE SURE THE VALVE YOU BUY BEARS THE WORDING:

PATENTED

This Moorhead Valve is licensed under the Fleming Patent—
Number 803684—for amateur and experimental purposes only.

TERMS: Cash with order, or C. O. D.
The prices of all our goods are F. O. B. San Francisco.

FOREIGN ORDERS: A draft or money order covering the cost of the goods purchased must be enclosed with all orders from outside the United States, or from the U. S. Territories, and all expenses such as freight, insurance, etc., connected with the shipping of the same must be remitted to us on receipt of the merchandise, which is forwarded at purchaser's risk.

All previous prices, terms and discounts are hereby cancelled.
No exclusive territories allotted to agents or dealers.

PACIFIC LABORATORIES SALES DEPARTMENT

510 PACIFIC BUILDING — SAN FRANCISCO, CAL.

Fig.9. Moorhead prepared a price sheet circa March 1919 to advertise four vacuum valves designated Relay for detection/amplification/oscillation, Type R for reception, Type RH as an oscillator and amplifier, and Type B for transmitting—described as being exactly the same as that being furnished to the U.S. Navy. (Courtesy Stew Oliver)

suit and then settling the next day, the DeForest Company was assured that it would retain the proceeds specified in the agreement—an agreement that could be viewed legally as the "settlement agreement" ending the lawsuit. Indeed, the lawsuit was reported in the *San Francisco Chronicle* on April 30, 1919, and a settlement to the lawsuit, which was characterized as a "friendly suit," was reported the very next day on May 1, 1919.[14] DeForest may also have believed that his lawsuit would forestall AT&T from suing Moorhead in the future.

Marconi attorneys must have been aware of the shortcoming of the purported license granted to Moorhead by DeForest because they developed a contingency plan in conjunction with Otis Moorhead and Lee DeForest whereby, if necessary, Moorhead would become an employee of the DeForest Company and arrange to have tubes manufactured for DeForest in the Moorhead Labs facility under a personal license from DeForest. By terms of the agreement with AT&T in 1917, DeForest was allowed to manufacture tubes under a personal license, and by hiring Moorhead as an employee, DeForest would, in effect, be making the tubes. However, Marconi needed to make a new licensing agreement with Otis Moorhead as an individual in the event he left Moorhead Labs. A new agreement signed on the same date as the Moorhead–DeForest agreement was executed in which Otis Moorhead as an individual agreed to assume all contractual obligations of Moorhead Laboratories in the original licensing agreement with Marconi dated Nov. 30, 1919 if Moorhead were to leave the employment of Moorhead Laboratories.[15] Moorhead Laboratories was also a party to the new agreement, agreeing that if Otis Moorhead left Moorhead Laboratories, Marconi's license with Moorhead Laboratories would be automatically cancelled. In this event, Otis Moorhead as an individual would be licensed to legally manufacture tubes for DeForest as his employee.

The third and final agreement signed on April 30, 1919 was an agency agreement between Marconi,[16] Otis Moorhead and Moorhead Laboratories whereby Marconi acquired selling rights for any tubes made by either Otis Moorhead or the Moorhead Company under the Fleming and Deforest patents, except for tubes made for the U.S. Government.[17] In essence, Marconi would be Moorhead's sole agent for selling tubes to amateurs and experimenter as well as to foreign governments. This agreement replaced the original agreement dated Nov. 30, 1918, which had no reference to Marconi as a sales agent. Clearly, Marconi executives had changed their minds and decided to get into the business of selling vacuum tubes.

It was not long before Marconi executives and their attorneys determined that Marconi's agency agreement with Moorhead dated April 30, 1919 was something of a mistake because it violated the terms of the DeForest–AT&T agreement of 1917 in which DeForest was identified as the sole distributor for tubes manufactured under his personal license. At this point, representatives for the three parties met in San Francisco in May of 1919, at which time they agreed to scrap the four previous agreements and replace them with three new agreements dated June 6, 1919, which were intended to meet the spirit if not the letter of the requirements of the 1917 AT&T–DeForest agreement.

First, Marconi and Moorhead signed a new licensing agreement dated June 6, 1919 similar to the one they signed on Nov. 30, 1918, but reducing the scope of the license under the Fleming patent to tubes manufactured for sale only to the U.S. government.[18] Second, DeForest and Moorhead signed a new agreement dated June 6, 1919 specifying that Otis Moorhead was to become a contract employee to manufacture tubes only for the DeForest Company, that Otis Moorhead would sell tubes to DeForest for "$2.40 complete in quantities as ordered," and that Otis Moorhead and Moorhead Laboratories would turn over any orders received in the future to DeForest with the notable exception of orders from the U.S. Government.[19] The Moorhead–Marconi and Moorhead–DeForest agreements were crafted to allow Moorhead to continue to sell tubes directly to the U.S. Government at whatever price structure had been agreed upon. Third, Marconi and DeForest signed a new agency agreement specifying that Marconi was to be the sole selling agent and distributor for the tubes made by Moorhead for the DeForest Company.[20] The agreement specified that Marconi would pay DeForest $3.20 for each tube, and that DeForest had the right to repurchase the tubes from Marconi at a minimum price of $5.00.

These three agreements set out substantially different positions for the three entities as compared to the positions set out by the first four that were nullified. First, Moorhead became a contract employee of the DeForest Company from the outset. Second, Marconi became the sole sales agent for DeForest (in lieu of Moorhead) insofar as vacuum tubes were concerned. Third, because the Moorhead–Marconi and Moorhead–DeForest agreements specified a pricing structure, there was no need for DeForest to issue any type of licensing agreement to either party, which DeForest was not legally able to do without violating his 1917 agreement with AT&T. Fourth, Moorhead was able to continue selling tubes directly to the U.S. Government. When the news of these agreements reached the press circa June 1919, it was hailed under the headline "Radio Vacuum-Tube Litigation is Settled," with the tagline "Excellent Market for Thousands of Bulbs a Month in Prospect Now that the Three Rival Manufacturing Concerns Have Come to Agreement."[21]

Marconi Introduces the V.T. Vacuum Tube

According to a memo from Marconi Commercial Engineer George W. Hayes to David Sarnoff on Dec. 27, 1919, Marconi placed two orders for tubes immediately after closing contracts with Moorhead and DeForest, the first calling for 10,000 tubes and the second for 20,000, amounting to a total of 30,000 tubes. No reason was given for splitting the order into two parts, but it was clear that only hard tubes exactly like the SE-1444 were ordered. That Marconi initially decided to sell only hard tubes is evident from the first ads Marconi placed for the V.T. in the July 1919 issues of *The Wireless Age* and *QST*. This ad reproduced here as Fig. 10 mentions only one tube type: "A highly developed, all-around tube for use as a detector and amplifier in wireless communication." To support this decision, Marconi prepared an article for the August issue of *The Wireless Age* aimed at the radio amateur that touted the virtues of a single tube for both detection and amplification.[22] The article began with the premise that "a good majority of the amateurs are not in a position to purchase a family of vacuum valves." It went on to state, "The Marconi Company has provided an all around detector of uniform operating characteristics which may be said to represent an average of the good points of all vacuum tubes." It concluded with a schematic of a receiver for "amateur experimenters who desire to work their 200 meter sets over great distances" with a detector stage and two stages of amplification using the same hard V.T. tube for all three stages.

While Marconi had initially decided to sell only hard tubes, there was a great deal of controversy about this decision. DeForest had urged Marconi to sell soft tubes of the "gas type," noting that "it will be but a short time before the amateur who purchases these tubes will make every effort to buy the old type audiotron of Type T DeForest tubes which are being advertised at present in all the radio magazines." On the other hand, Alfred N. Goldsmith, Director of Research for American Marconi, urged Marconi not to sell soft tubes "in view of their available characteristics, non-uniformity and unreliability as detectors and oscillators."

Marconi executives held a meeting on June 24, 1919 in which Sarnoff made a decision to offer two types of tubes—a "Class I" soft tube with a plate voltage of "60 volts down" designed for use as a detector and a "Class II" hard tube with a plate voltage between 60 and 110 volts designed for use as an amplifier and oscillator. It could not have been lost on Marconi executives that Elmer Cunningham began to market his soft AudioTron tube in June 1919, one which had been very popular among amateur radio enthusiasts before the war.[23] Ads placed by the AudioTron Company did not mention prices, but ads placed by agents for AudioTron did. For example, an ad placed in the July 1919 issue of *Wireless Age*—Marconi's own magazine—by The Radio Apparatus Co. cited a price of $5.00 postpaid for the Audiotron detector valve, approximately 30% less than Marconi's price of $7.00 for the V.T.[24] Undoubtedly, this ad submitted in June for the July issue would have arrived at the offices of Marconi well before Sarnoff's June 24th meeting.

Marconi offered both tube types in the August and September issues of *The Wireless Age* (see Fig. 11), but for

July, 1919 EXPERIMENTERS' WORLD 35

THE ONLY VACUUM TUBE WHICH AMATEURS CAN USE

Agreements recently effected have made vacuum tubes available for experimental use. The Marconi V. T. is the only vacuum tube, or audion, which may be sold to amateurs, laboratories, schools of instruction and experimenters.

Fleming Pat. No. 803684
De Forest Pat Nos. 841387-879532

MARCONI V. T.

$7.00 each

Standardized base . . . $1.50 additional

A highly developed, all-around tube for use as a detector and amplifier in wireless communication. It has practically the same electrical constants as the tube used by the Allied armies and navies throughout the war in continuous wave transmission and reception. The terminals of the elements of the tube are brought out to a 4-prong standardized base, fitting into the standard four-contact bayonet sockets.

Filament current, 0.7 ampere. Filament potential 4 to 6 volts.
Plate potential, 20 to 60 volts for reception.

For lighting filaments a *lead* storage battery is preferable because of its constancy of voltage. Ordinary dry cells or flashlight batteries may be used to provide the plate voltage.

The approximate operating life of the MARCONI V. T. is 1,500 hours.

Delivered postpaid in special container insured against breakage to any address upon receipt of purchase price.

COMMERCIAL DEPARTMENT
Marconi Wireless Telegraph Co. of America
Sole distributors for De Forest Radio Telephone & Telegraph Co.
Woolworth Building, 233 Broadway, New York

When writing to advertisers please mention THE WIRELESS AGE

Fig.10. Marconi's first V. T. ad introduced only a single tube type that was advertised as an all-around tube for both detection and amplification. (*Wireless Age*, July 1919, p. 35)

some reason the ads Marconi placed in the August and September issues of *QST*—the premier magazine for amateur radio enthusiasts—did not offer the soft tube. This oversight coupled with the article in the August issue of *The Wireless Age* touting the hard tube for use as both a detector and amplifier prompted *QST* editor Karl E. Hassel to publish an article in the September issue to "correct a misrepresentation which has evidently arisen in the minds of many amateurs concerning the high vacuum V.T.'s developed for the government during the war."[25] In the introduction to his article, Hassel noted that the hard tubes developed during the war had an advantage when used as amplifiers or oscillators, but "it is a sad fact that they are woefully insensitive in detection as compared with our amateur tubes." He pointed

July 1919 Wireless Age

A highly developed, all-around tube for use as a detector and amplifier in wireless communication. It has practically the same electrical constants as the tube used by the Allied armies and navies throughout the war in continuous wave transmission and reception. The terminals of the elements of the tube are brought out to a 4-prong standardized base, fitting into the standard four-contact bayonet sockets.

Filament current, 0.7 ampere. Filament potential 4 to 6 volts.
Plate potential, 20 to 60 volts for reception.

For lighting filaments a *lead* storage battery is preferable because of its constancy of voltage. Ordinary dry cells or flashlight batteries may be used to provide the plate voltage.

The approximate operating life of the MARCONI V. T. is 1,500 hours.

August 1919 Wireless Age

A highly developed, all-around tube for use as a detector and amplifier in wireless communication. It has practically the same electrical constants as the tube used by the Allied armies and navies throughout the war in continuous wave transmission and reception.

The approximate operating life of the MARCONI V. T. is 1,500 hours.

Class I.—Designed for use as a detector; operates with plate potential of 20 to 60 volts.

Class II.—Designed for use as an amplifier; plate potentials from 60 to 110 volts may be applied.

Tubes in either class may be used for detection or amplification, but those of Class I are best as detectors, and Class II tubes are superior as amplifiers.

Fig.11. Marconi offered two tube types for the first time in the August 1919 issue of *Wireless Age*—a Class I detector and a Class II amplifier; compare the ad excerpt from the July issue (upper) with the one from the August issue (lower).

out that the hard vacuum tubes developed for the military had great merit for special work (e.g., airplane communication, use by unskilled operators) due to their ruggedness and stability, but they were not suitable for amateurs who were interested in long-range communication requiring the most sensitive detectors available. Hassel concluded his introductory note by saying: "We believe there is no reason for yearning for war-time tubes for detectors as long as we have the present good amateur tubes now on the market." What other tubes were on the market? Well, Milton B. Sleeper, editor of "The Radio Department" section of *Everyday Engineering Magazine* answered that question in an article appearing in the August 1919 issue of that magazine: "At the present time the Audiotron and Moorhead-de Forest tubes are the only ones available to the general public."[26]

Given the resistance from the amateur radio community to purchasing hard tubes for detectors, Sarnoff must have been well satisfied with his decision to sell both tube types. However, by August of 1919—the same month that Marconi ads first appeared for the soft Class II tube—engineer F. H. Kroger from the Marconi test lab reported to management that 70% of the first 5,000 soft tubes Marconi received from Moorhead failed to pass the required test specifications. In a meeting on Nov. 6, 1919 attended by Sarnoff, Marconi engineers and representatives from Moorhead, it was agreed that Moorhead's soft tubes lacked consistency and reliability, and that Marconi would order only hard tubes in the future. Sarnoff directed that all 6,632 rejected tubes (including both soft and hard) returned to Moorhead in October were to be replaced by hard tubes. The hard tubes were "to be suitable for use as transmitters and amplifiers, but their detector characteristics are to be of a small order." Sarnoff then instructed the marketing department to "educate purchasers as to desirability of using hard tubes as opposed to soft tubes."

Sarnoff's decision to sell only hard tubes became immediately evident in Marconi ads placed in *Radio Amateur News* beginning in December 1919 and in *QST* beginning in January 1920. All references to Class I and Class II tubes disappeared, and thereafter were characterized in Marconi ads as the "Marconi V.T." Marconi also began to place articles in radio magazines and journals extolling the virtues of the Marconi V.T. for amplification and detection without any reference to classes of the tube. For example, an article entitled "Experimental Wireless Telegraphy and Telephony" appearing in the November 8, 1919 issue of the weekly *Scientific American Supplement* stated that all V.T.'s "possess identical operating characteristics," and that the Marconi V.T. is "an all-round detector, one which can be used in any sort of detection or amplification circuit."

Marconi's position favoring the hard tubes was occasionally challenged by well-known writers such as venerable radio operator, E. M. Sargent, who wrote an article in the January 1920 issue of *Radio Amateur News* to give the experimenter a good understanding of how the detector operates and how the amateur could get the best results.[27] He divided vacuum detectors into two groups—high vacuum and low vacuum or gaseous—and stated unequivocally that the gaseous tubes "are by far the more sensitive." He went on to state "the Army and Navy tubes were as a rule inferior to the tubes used by the amateurs before the war and were used only because of their uniformity and reliability under all different adjustments." He explained the reason for the sensitivity as follows: "The gas tube… has a characteristic curve that follows the general form of that of a high vacuum tube, but has irregularities in it, (Fig. 12). When the tube is adjusted so that the working point comes at one of these irregularities extreme sensitivity results." He went on to explain how the irregularity works to increase sensitivity, and concluded: "While it is difficult to maintain the working point at exactly the right place, it is by no means impossible." A better description of why these irregularities give such good results as a detector can be found in an article by M. L. Snyder in *The Wireless Age*.[28]

Despite the "bad press" in radio magazines on the use of high-vacuum tubes as a detector, Marconi continued to advertise and sell only the high-vacuum version of the Moorhead V.T. up to the time it was merged into RCA on Nov. 20, 1919. RCA, as successor to American Marconi, continued Marconi's policy of selling only hard tubes for the remainder of the time that

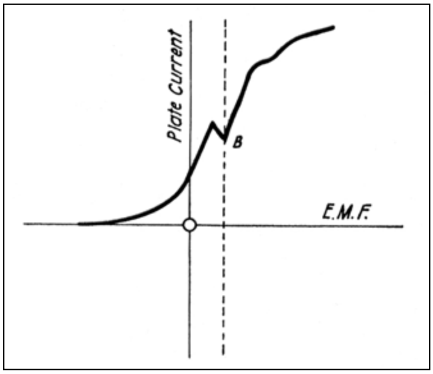


Fig.12. The characteristic I-V curve of the gas type of detector has inflection points where the positive and negative portions of received signals are additive, thus making the detector a very sensitive rectifier. (*Radio Amateur News*, Jan. 1920, p. 356)

Moorhead tubes were manufactured under the three-party agreements.

Marconi Tube Markings

Approximately half of the tubes ordered in each of the two contracts Marconi executed with Moorhead in 1919 were Class I soft tubes and the other half were Class II hard tubes. Despite the fact that Marconi ads identified its tubes as Class I and Class II, most of the 10,000 tubes manufactured by Moorhead under the first contract were identified as either Class II hard tubes by the letter A stamped on the glass envelope, or Class I soft tubes by the letter B stamped on the glass. The words "Moorhead Laboratories," most often followed by "San Francisco," were stamped on the glass without any reference to the Marconi Company (see Fig. 13), and serial numbers were also stamped on the glass of all tubes. The

Fig.13. This Class II tube with a serial number 93 was stamped with the letter A and Moorhead Laboratories followed by San Francisco on the glass envelope.

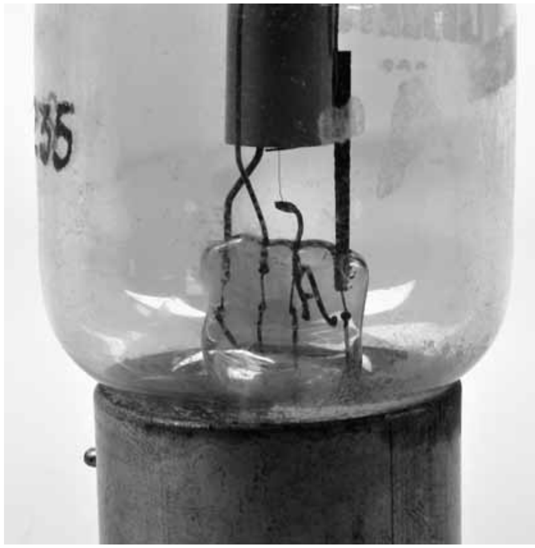


Fig.14. A number of the hard tubes stamped with A on the envelope were also inked on the press with either the numeral 2 or the letter A, which appears here.

serial numbers observed on Type A tubes manufactured under the first contract range from 93 to 5,941.[29] Some tubes with an A on the glass were also inked with the letter A or the numeral 2 on the press (see Fig. 14). Soft tubes manufactured under the first contract with letter B stamped on the glass have been observed with serial numbers between 223 and 2,856,30 and some of these tubes were also inked with a B or 1 on the press. A small number of both soft and hard tubes were observed without any letter stamped on the glass, but they were generally identifiable by the letter or numeral inked on the press.

Approximately 20,000 tubes were manufactured under the second contract, half soft and half hard. Hard tubes stamped with the letter A have been observed with serial numbers ranging from 200,200 to 207,184, and many of these also had an A or 2 inked on the press. At a serial number somewhere between 207,184 and 207,547, the marking on the glass envelopes of the hard tubes changed from A to V.T. (Fig. 15), which finally brought the marking on the tube into line with the V.T. appearing in Marconi ads. Thus, the hard tubes in the second contract consisted of approximately 7,400 tubes stamped with A and another 9,200 tubes stamped with the V.T. for a grand total of 16,600 hard tubes, which consisted of the original 10,000 hard tubes ordered plus an extra 6,600 hard tubes to replace rejected soft and hard tubes from both contracts. The 10,000 soft tubes manufactured under the second contract have been observed with serial numbers stamped on the glass between

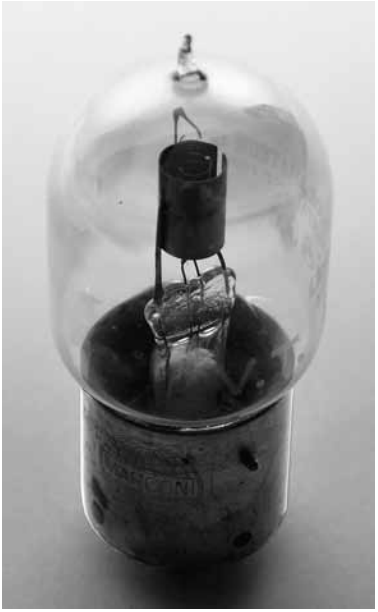


Fig.15. The last 9,200 or so hard tubes manufactured for Marconi under the second contract were stamped on the glass with the V.T. legend, and on the Shaw base with the Marconi globe logo, DeForest name, and patent information.

Fig.16. A small number of tubes with no letter stamped on the glass were rubber-stamped on the base with the appropriate class, such as this soft tube with the Class I stamp.

100,141 and 109,846. A very small number of soft tubes manufactured under the second contract have no B stamped on the glass, but they can be identified as being soft by the numeral 1 inked on the press, and in some cases by the legend "Class I" rubber-stamped on the base (see Fig. 16). Similarly, the Class II stamp has been observed on a few hard tubes manufactured under the second contract. Only one soft tube from the second contract has been observed with the V.T. marking on the glass.

The Marconi name and V.T. globe logo that appeared on the glass of the tubes in Marconi ads never appeared on the glass of any tubes sold by Marconi. According to Marconi documents, the Marconi V.T. globe logo and the DeForest name and patent legends were stamped on the brass base of all hard tubes on the second contract, which had serial numbers in the 2xx,xxx series. However, about half of these tubes with serial numbers linking them to the second contract have been observed without any stamping on the brass bases. A strong case will be made in Appendix A that many of the hard tubes without legends stamped on the brass bases were actually manufactured and sold by Moorhead Labs after the three-party agreements were cancelled using duplicated serial numbers to hide the fact they were making so many tubes. No tubes from the first contract have been observed with the Marconi/DeForest stamp on the base, and only a few soft tubes from the second contract have been observed with this base stamping.

Two other physical features of tubes manufactured by Moorhead for Marconi are worth noting. First, while Marconi ads never pictured tubes with spherical glass bulbs, it is estimated that several thousand tubes, both hard and soft, were manufactured with spherical glass bulbs (see Fig. 17). No reason has been given for manufacturing a relatively small number of spherical tubes that required a larger box to accommodate the larger diameter of the spherical tubes (see Appendix B). Second, many but not all of the hard tubes have a soft gold color caused by the getter material used to achieve higher vacuums than those achieved in soft tubes, which did not have getters (see Appendix B).

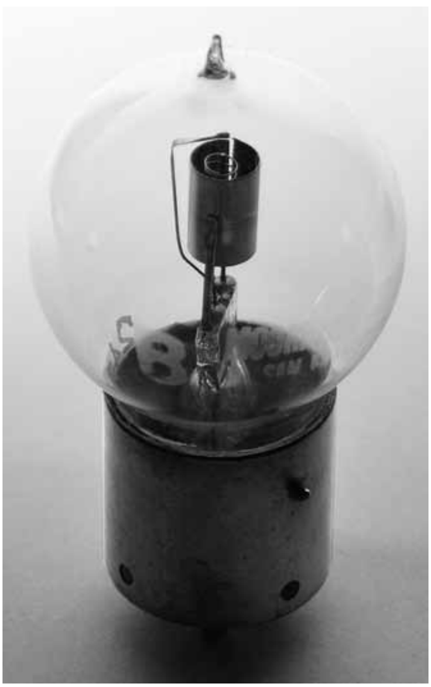


Fig.17. This rare Class I spherical tube is stamped on the glass with the serial number 583, the letter B, and Moorhead followed by San Francisco.

Test and Evaluation of Moorhead Tubes

Many historians blame Moorhead Labs for poor quality control in the production of its tubes, and some have concluded that Moorhead's difficulty in providing enough acceptable tubes to meet Marconi's demand contributed to Marconi's decision to terminate the three-party agreements. However, a careful reading of the pertinent documents tells a somewhat different story. To be sure, there were some problems with the tubes that Moorhead shipped to Marconi, but the real problems were with Marconi's test procedures.

The Marconi–Moorhead contract stated that all tubes were to pass the Navy test procedures, which were specified in a Navy document dated April 8, 1919 issued for the Navy–Moorhead Contract 45217.[31] However, Marconi did not initially follow the test procedures defined therein. For example, the Navy contract with Moorhead called for testing the hard SE-1444 tube for excessive gas by first applying 40 volts to the plate and then 100 volts, and rejecting any tubes that exhibited a blue glow at either voltage, which would indicate the tube was excessively gassy. However, Marconi decided to test the hard tubes it ordered at 300 volts and found that a majority of the tubes did not pass this "blue glow" test. They were returned to Moorhead where they were retested and most were found to pass the Navy test at 100 volts. Moorhead pointed out the problem to the Marconi Co., who ultimately changed the test procedures to agree with those of the Navy—but not until December 1919 after testing almost 30,000 tubes at the higher voltages. Indeed, a later Marconi publication dated March 1920 confirmed that Marconi had been testing Class II V.T. tubes at 350 volts and rejected them if they did not pass.[32]

The real problem for Marconi arose shortly after Sarnoff decided to sell soft tubes. A memo dated August 19, 1919, reported that 5,000 soft tubes had been tested and found that only 30% had passed. However, Marconi chose to test the soft tubes using the same standard test conditions used for the hard tubes. Moorhead sent a telegram to Marconi by way of Randall Keator on Sept. 30, 1919 stating that all of the soft tubes are equally sensitive if proper care is taken in adjusting plate and filament voltage, and while this takes time, the amateur is willing to do this.[33] Moorhead further stated that one could not expect the sensitiveness of soft tubes to be equal on a standard adjustment, and that plotting characteristic curves clearly shows this to be true. Keator related the information in this memo to Sarnoff in a meeting on Nov. 6, 1919, pointing out that the Navy had come to the same conclusion two years earlier and for that reason decided not to purchase soft tubes. In fact, no Navy standards or instructions for acceptance testing of soft tubes had been created, and so whatever tests Marconi performed and whatever criteria Marconi used to accept or reject soft tubes were inconsistent with the Marconi-Moorhead agreement.

Despite involvement by Alfred N. Goldsmith, there was apparently no resolution to the problem of specifying appropriate acceptance tests for soft tubes. According to a memo from Goldsmith to F. H. Kroger at Marconi dated July 16, 1919, Goldsmith steadfastly urged Marconi management to stop selling soft tubes altogether. While Marconi attempted to develop test specs for soft tubes, the decision was made to test the soft tubes at 60 volts where the detection efficiency seemed to be better, and reject only those tubes with mechanical problems, burned-out filaments or those with responses so low that they could be characterized as "dead." In the end, Sarnoff decided that gas tubes were not sufficiently uniform or reliable, and were also too difficult and time consuming to test, which prompted his decision at a Nov. 6, 1919 meeting to announce that Marconi would stop selling soft tubes altogether. At the same meeting Sarnoff directed that new specs for hard tubes were to be drawn up, following those for Navy Type SE 1444. Indeed, Marconi stopped advertising Class I soft tubes beginning with the December issues of *The Wireless Age, Electrical Experimenter, and Radio Amateur News,* and the January issue of *QST.*

The number of rejected tubes waxed and waned over a period of five months, but by the end of November, a total of 30,795 tubes had been received and tested at Marconi's Aldene, NJ factory, and a tally of accepted, rejected and returned tubes appeared in a document dated Nov. 25, 1919. The results are summarized in Table 2, where it can be seen that the total number of tubes rejected—including those on hand and those returned—was 6,644 out of a total of 30,795, for an overall rejection rate of 21.6%. In another memo, the reasons stated for rejecting soft tubes were burned out filaments (8%) and dead tubes (10%), while the reasons for rejecting hard tubes were burned out filaments (6%), gassy or soft tubes (20%), and mechanical problems (1%). More hard tubes were rejected (27%) than soft tubes (18%), primarily because of excessive gas in the hard tubes (20%). However, a number of the hard tubes initially rejected for being gassy were subsequently accepted and sold as soft tubes. By November, Marconi had in stock and ready to ship 8,491 Class I tubes and 5,751 Class II tubes, a supply that would last Marconi through Dec. 1, 1920 when GE began to supply tubes to RCA. According to the records, neither Marconi nor RCA was ever short of Moorhead tubes to ship.

Tubes (11/25/1919)	No.
Shipped to date	9883
Returned	1963
Rejects on hand	4681
Class I in stock	8491
Class II in stock	5751
Unaccounted for	26
Total	30,795

Table 2: Marconi Tube Accounting as of Nov. 25, 1919 (Marconi Co. memo)

Marconi Cancels the Agreements

The three-party agreements dated June 6, 1919 had been in effect for less than seven months when Marconi abruptly cancelled the agreement with Moorhead Labs and DeForest without warning by letters dated January 30, 1920 from John W. Griggs as President of Marconi. The letters cited the clause in the agreement permitting either party to cancel for any reason by giving a six-month notice from the date of mailing. Consequently, the effective date of termination of the agreements was July 30, 1920. The proximate cause of the cancellation has often been stated as a letter sent to the DeForest Company by AT&T dated Oct. 8, 1919, with a copy going to the Marconi Company.[34] In this letter AT&T asserted that the arrangement between the DeForest and Marconi Companies was in violation of the 1917 agreement between DeForest and AT&T. The first violation cited was the sale of tubes to "amateurs, laboratories, schools of instruction and experimenters," whereas the 1917 agreement specified that tubes could be sold only to amateurs. The second violation cited was DeForest's sale of tubes to Marconi for resale, whereas the 1917 agreement stated that the tubes sold by DeForest could not be "used by others than the original purchaser or lessee."

It is much more likely the decision to cancel the agreements was prompted by two identical letters dated Jan. 5, 1920 sent by A. J. Hepburn, Acting Chief, Bureau of Steam Engineering, to Albert G. Davis at GE and George E. Folk at AT&T.[35] These letters stated in part: "Now, the [vacuum tube] situation has become such that it is a public necessity that such arrangement be made without further delay, and this letter may be considered as an appeal, for the good of the public, for a remedy to the situation." Davis testified at the FTC hearings that this letter prompted the negotiations between AT&T and GE to cross-license patents for vacuum tubes as well as a host of other radio technologies: "It [the Hepburn letter] came pretty nearly being an order. It was as much of an order as the Navy could issue. Oh yes. It was this undoubtedly that precipitated the negotiations."[36] While cross-licensing discussions had been dragging on for years between Marconi and AT&T before the creation of RCA, negotiations between GE and AT&T began in earnest as a result of these letters. It was much more likely that the anticipation of a cross-licensing agreement between GE and AT&T caused RCA/GE management to direct the cancellation, which would allow GE to manufacture tubes for RCA—and not just for sale by RCA to amateurs, but also for use in RCA's commercial communication network.

Marconi cancelled not only the licensing agreement with Moorhead and the agency agreement with DeForest on Jan. 30, 1920, but also an order for another 20,000 tubes it had placed with DeForest/Moorhead in November of 1919. Unlike the licensing and agency agreements requiring a six-month notice of cancellation, the individual tube orders apparently did not require a notice period because upon receipt of the cancellation notice, Moorhead Labs immediately stopped producing tubes, and the order for 20,000 tubes was never filled.

Internal Marconi and RCA correspondence made it clear that the two companies had placed orders for and received a total of 30,000 acceptable tubes pursuant to the two known orders, plus a small number of additional tubes of unknown types. A Marconi factory tube report dated March 24, 1920 accounted for the tubes received from Moorhead as follows: the total number of tubes shipped from the factory was 32,570, and the number of rejects returned to Moorhead was 6,721. There was no explanation in the discrepancy between the 32,570 tubes actually shipped and the two orders placed for 30,000 tubes. There may have been other tubes such as the Type C transmitter tube that may help account for this difference. Marconi was known to order Type C tubes from Moorhead for use in a radiotelephone project in Cuba, and was also known for clandestine use of triodes in its commercial work.

Another Marconi memo issued from the manager of the Sales Department dated April 18, 1924 listed the sales of V.T. tubes from June through December of 1919 at 8,317, and sales from January to December of 1920 at

20,876, for a grand total of 29,193 tubes. December 1, 1920 was cited as the date when Marconi stopped selling Moorhead V.T. tubes altogether. Again, there is no reconciliation of the discrepancy between the 29,193 tubes sold and the 30,000 tubes ordered or the 32,570 shipped as of March 24, 1920—seven months earlier. Perhaps the difference between the number shipped and the number sold was due to tubes accepted by the Marconi factory from Moorhead but returned by the customer to Marconi and replaced under warranty without charge.

Henry Shaw Gains Control Of Moorhead

Even before Moorhead Labs received the cancellation notice from John W. Griggs dated Jan. 30, 1920, Moorhead Labs was experiencing financial troubles. While a newspaper article placed by Otis Moorhead in the *San Francisco Chronicle* on September 14, 1919 would seem to indicate its financial condition was improving,[37] another article appearing in the *San Francisco Bulletin* on Oct. 4, 1919 cast doubts by stating that while Moorhead's indebtedness of $25,000 was offset by $30,000 owed by Marconi for tubes shipped, much of that amount was disputed because the "specifications were not lived up to."[38] Several months later an article appeared in the *San Francisco Examiner* on January 18, 1920 announcing a reorganization of Moorhead led by Willard F. Williamson, a prominent San Francisco attorney who represented a number of shareholders.[39] He had replaced the existing board of directors with a "new and stronger board" that included himself, Charles M. Whitney of the Crown-Willamette Paper Company, and Otis Moorhead, who signed a six-year contract to stay on as President. The article ended with a statement by Williamson that "his clients, who now control the company, were amply able to provide such capital as might prove to be necessary."

No sooner had the article on the reorganization appeared in the newspaper than Otis Moorhead received the letter from John W. Griggs notifying him of the cancellation of the agreement between Moorhead and Marconi. This notice must have been too much for even Williamson and Whitney because the Moorhead factory closed at the end of January 1920, which according to Williamson was due to "depleted financial conditions."[40] An announcement of this reorganization did not appear in *Pacific Radio News* until the March 1920 edition, and it is curious that nothing was said in the article about the closing of the factory or the depleted financial condition.[41] Indeed, Otis Moorhead notified Henry M. Shaw, President of Shaw Insulator Company of Newark, by telegram circa March 13–14, 1920 that creditors were forcing Moorhead Labs into bankruptcy. Shaw had a significant interest in Moorhead Labs, not only as a creditor with an account exceeding $30,000 for brass tube bases, but also as a guarantor for Moorhead's glass account with Corning Glass and its tube pin account with the Erickson Company of Brooklyn.[42] Shaw responded to this telegram by departing from his home in New Jersey the next day for San Francisco, where he indeed found that operations had ceased. He immediately began to straighten out the affairs of Moorhead Labs, arranging for a $50,000 loan from a local bank to allow the company to reopen in early April 1920.[43] He met with creditors and directors, persuading them not to force the company into bankruptcy.

The company was reorganized once again, this time with Shaw being named as president effective April 1, 1920. The reorganization was formalized at the annual meeting of stockholders held in Seattle from May 3–5, 1920, at which time Williamson, Whitney, and Moorhead were reelected as directors, and Henry Shaw and G. C. Stephens, an investment banker of Stephens & Co. in San Francisco, were elected as two new directors.[44] This reorganization was reported more fully in the June 1920 issue of *Pacific Radio News*, where it was mentioned that Ellery W. Stone had been appointed general manager, Otis Moorhead had been named Chief Engineer, and that Shaw had created two companies for distributing Moorhead tubes—the Pacific Radio Supplies Company in the west and Atlantic Radio Supplies Company in the east.[45]

In a second article also appearing in the June issue of *Pacific Radio News*, the closing of a "big radio deal" was announced in which Henry Shaw and Lee DeForest acquired a large interest in the Moorhead Laboratories. It would come out later in a letter from L. F. H. Betts to A. G. Davis, VP of GE, that Shaw controlled 75% of the stock of Moorhead Labs, and the two managed the company from the Board as directors. The article went on to say that Moorhead Labs "has hitherto marketed its product in the United States through the agency of the latter company [e.g., Marconi], but will shortly enter the wholesale and retail field itself." DeForest was quoted in this article as saying that wireless telephones would be a major new market for Moorhead tubes. DeForest's interest in Moorhead Labs and its tubes was apparently related to Lee DeForest, Inc., a new company he had established in San Francisco a few months prior for the purpose of manufacturing Radio Telephones.[46]

Shaw Markets Moorhead Tubes

Henry Shaw's first overt action as president of both Moorhead Laboratories and the newly created sales organization, Pacific Radio Supplies Co., was to advertise Moorhead tubes for sale in several national radio magazines. His first ads appeared in May of 1920, the very month after RCA ran its last ads as the sole distributor for the Marconi V.T. tube. Shaw placed two distinctly different ads in May 1920 issues of national radio magazines, the first appeared in *Pacific Radio News* that introduced what were ostensibly two new tube types for experimenters—the Moorhead Electron Relay and the Moorhead V.T. Amplifier-Oscillator (see Fig. 18). However, neither tube was new. The unbased Electron Relay pictured in the ad was described as "the

Fig.18. This May 1920 Moorhead ad in *Pacific Radio News* offered an unbased Moorhead Electron Relay detector and the SE-1444 described as the Moorhead VT Amplifier-Oscillator.

original tubular vacuum valve, brought out by this company in 1915, and is an excellent detector." Indeed, it was the double-ended tubular Electron Relay sold to the public before the war. The Moorhead V.T. Amplifier-Oscillator pictured in the ad was described as "the Navy SE 1444 'hard' tube…for amplification and oscillation purposes." A distinctly different ad appeared in *Electrical Experimenter*, *Radio Amateur News* and *Everyday Engineering* that also featured what were ostensibly two new tube types (see Fig. 19). One was the Moorhead V.T. Amplifier-Oscillator, which was described as being "similar to the Navy 'hard' tube," while the other was designated the "De Forest 20 Audion Detector" with a Navy standard base, which was indeed a new tube—not the unbased Electron Relay that appeared in *Pacific Radio News*.

The two different ads appearing the same month present two separate conundrums: 1) what is a DeForest 20 Audion Detector and was it ever made, and 2) why did Shaw place two such different ads with two different soft tube types in different radio magazines in the same month. Tyne pictured a tube he claimed was this DeForest 20 in *Saga of the Vacuum Tube*,[47] and further claimed that the DeForest 20 was introduced first and the Electron Relay was introduced later. However, the tube appearing in his book was not marked as a DeForest 20, nor has any tube ever surfaced with that marking. Bill Condon believed that the tube pictured in Tyne's book was actually a DeForest DV-6 of 1923 vintage. The DeForest 20 tube was never advertised again, there are no other known references in the literature to such a tube, and there are no known pictures of this tube—notwithstanding the tube pictured in Tyne's *Saga*. So, for all intents and purposes the phantom DeForest 20 does not exist and never did. One has to ask, why would DeForest have manufactured any type of tube ready for sale in May of 1920 when he was precluded from selling any tubes before the expiration of the Fleming patent in late 1922 by injunction resulting from the Marconi v. DeForest lawsuit in 1916? Not only that, he was also precluded from selling any tubes under the agreements with the Marconi and Moorhead Companies dated June 6, 1919, which clearly stated that the DeForest company had appointed the Marconi Company its *sole* selling agent for its tubes: "DeForest Company…appoints Marconi Company and its duly accredited agents during the term of this agreement its sole selling agents and distributors of DeForest audion vacuum tubes for reception and amplification in the United States and its possessions, to amateurs, and for experimental purposes."[48]

The fact that two very different soft detector tubes were both introduced by Pacific Radio Supplies Company in ads appearing in May of 1920, albeit in different magazines, is a second conundrum that demands an explanation. Whatever the explanation, it must account for the fact that two different soft tubes were introduced in two different ads appearing the same month.

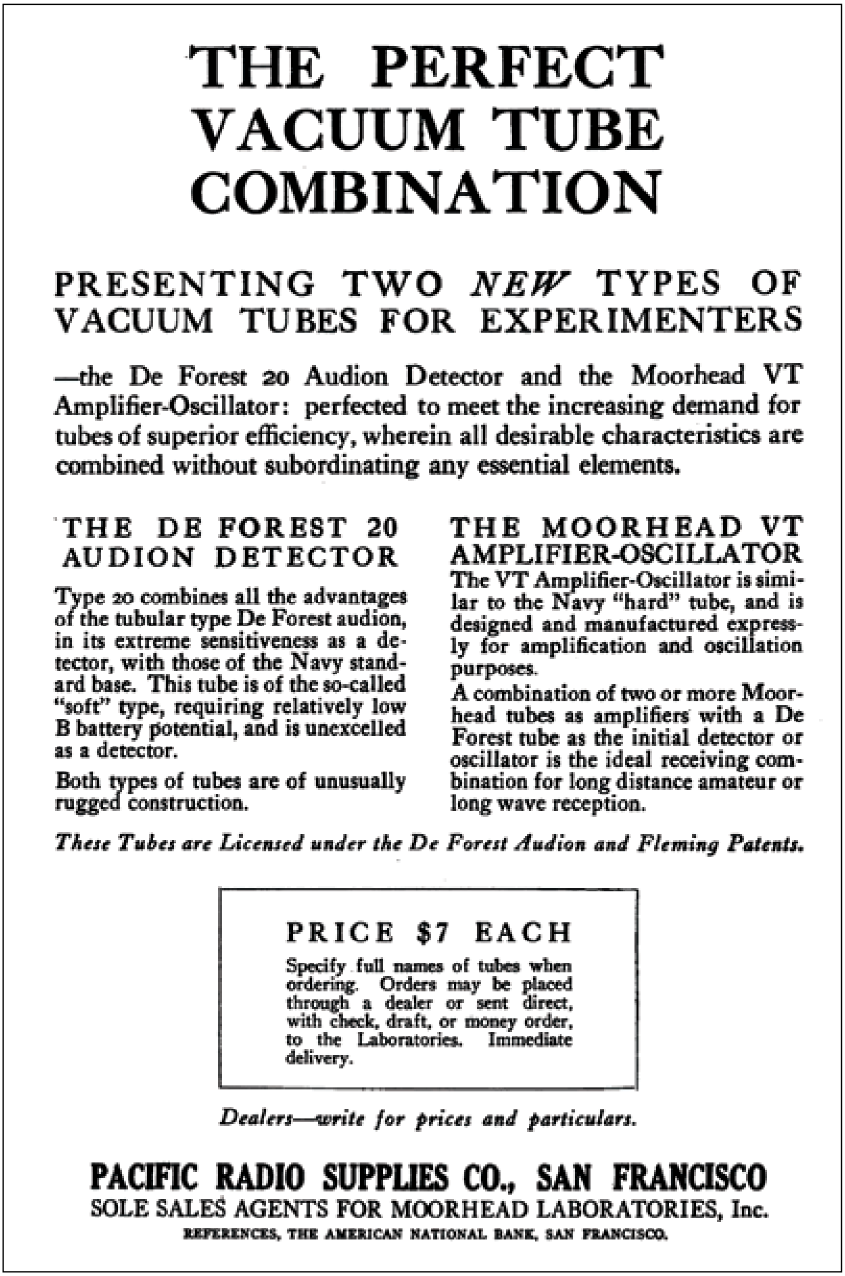


Fig.19. This May 1920 Moorhead ad appearing in the *Electrical Experimenter*, *Radio Amateur News* and *Everyday Engineering* offered a tube identified as the "De Forest 20 Audion Detector" and the "Moorhead VT Amplifier-Oscillator," which was described as being similar to the Navy hard SE-1444.

Tyne's explanation that the DeForest 20 was introduced first and the Electron Relay was introduced later does not pass this litmus test since both tubes were introduced simultaneously. The following explanation, while admittedly speculative, is consistent with all known facts.

It is likely that Henry Shaw submitted the same ad introducing the Moorhead V.T. Amplifier-Oscillator and the unbased Moorhead Electron Relay to all aforementioned publications in May of 1920. However, Shaw would not have been aware that Gernsback and other publishers of radio magazines had been threatened with lawsuits by letters from DeForest in July 1916 to discourage them from accepting ads for three-element tubes with internal grids that were not licensed by DeForest.[49] As a result, beginning in September of 1916 Gernsback and other publishers declined to accept ads for three-element vacuum tubes with internal grids unless they were licensed by DeForest. Gernsback was actually sued by DeForest in December 1916 because he advertised Moorhead and Tigerman three-element tubes with *external* grids, and although DeForest did not prevail, Gernsback did voluntarily accept an injunction against advertising internal grid tubes without a DeForest license to settle the suit.[50] Virtually all the other publications under the jurisdiction of the New York courts followed Gernsback's lead and did not accept ads for vacuum tubes with references to internal grids unless they were licensed by DeForest. However, *Pacific Radio News* was published in San Francisco, a jurisdiction where DeForest had been unsuccessful in obtaining injunctions against three-element tubes manufactured by both Moorhead and Cunningham. Thus, *Pacific Radio News* was virtually the only national radio magazine able to carry ads for three-element internal-grid tubes without fear of litigation by DeForest.

After the war, magazine publishers on the East Coast were still reluctant to take any ads for three-element internal-grid tubes without a DeForest license, and they refused to take any ads with photographs of potentially infringing tubes. When Henry Shaw prepared his Moorhead ads for the May issues of several radio magazines, he was almost certainly unaware of this proscription against ads with photographs of potentially infringing tubes. Gernsback, who was still under the injunction against ads for internal grid tubes without the DeForest license, could not have accepted this ad for publication in the *Electrical Experimenter* and *Radio Amateur News* magazines without exposing himself to sanctions from the New York Court for violating the injunction. After all, the very Electron Relay pictured in this ad was the specific target of the injunction. However, the publisher of *Pacific Radio News* willingly accepted Shaw's ad—complete with a photo of the Moorhead tubular Electron Relay tube—which did not have any reference to a DeForest license, just as he did before the war.

Shaw would have contacted DeForest, who was in San Francisco at the time, to seek a license so he could advertise Moorhead tubes in the magazines on the East Coast as well as the West Coast. DeForest would have told him that he could no longer provide licenses under the terms of the 1917 assignment of his patents to AT&T, and instead suggested that Moorhead manufacture a DeForest tube under his personal license, which was allowed under the terms of the AT&T assignment. DeForest would have recommended that Moorhead Labs manufacture a tube with all the advantages of the tubular type DeForest audion, in its extreme sensitiveness as a detector, with those of the Navy standard base (the exact words that appear in the East Coast ads in May 1920)—and why not name it the DeForest 20 Audion Detector for lack of a better name. Since there was no such tube, neither DeForest nor Shaw could produce a photograph or sketch for the ad, and rather than have a photograph of just one of the tubes—making it somewhat obvious that there was no DeForest 20 tube—Shaw opted for an ad with no photographs, the one that appeared in the May issues of magazines on the East Coast.

An alternative to the phantom tube theory is that DeForest suggested to Shaw that he manufacture a gassy version of the DeForest VT-21 supplied to the Signal Corps during the war. Support for this supposition comes from a handwritten note from Alfred Goldsmith to David Sarnoff dated July 16, 1919 at a time when Marconi was looking for an alternative to the Moorhead Class II tube (a gassy version of SE-1444). Based on a conversation with DeForest, Goldsmith writes, "In view of the fact that the DeForest Type T tubes were quite reliable and were so popular with the amateur, it would seem desirable to have Class 2 equal to them. As an alternative Class 2 might consist of a tube the same as the DeForest V.T. 21 which is a hard tube but a much better detector than our Class II and also operates on 20 to 40 volts. This tube is also well known to the amateur, who was in the Signal Corps and he would naturally compare…[unintelligible]". Perhaps the phantom DeForest 20 was actually the VT-21, which had a Shaw base (see Fig. 20)—or perhaps a soft version thereof.

Whatever the reason for the two different ads, Shaw and DeForest negotiated a deal during the month of May whereby the two gained controlling interest in Moorhead Labs and operated the Company from the Board as directors, a deal that was chronicled in the June issue of *Pacific Radio News*.[51] In essence, DeForest granted Moorhead Labs his personal license so the company could manufacture both the Electron Relay and the V.T. without violating the terms of the AT&T agreement. Cunningham reported back to RCA in a letter dated July 22, 1920 that DeForest had attached his personal license to Moorhead, and that Shaw and Moorhead Labs could claim without a serious challenge that the tubes made by Moorhead were licensed by DeForest. The pertinent portion of Cunningham's letter speculating that DeForest had granted Moorhead Labs his personal license is reproduced in Tube Tangle Part I.[52] Shaw's ads in June issues of popular radio magazines pictured a tubular audion with a standard four-prong base, but with the name Moorhead Electron Relay in lieu of the DeForest Type 20, which presumably was used as a placeholder for want of a better name. It is impossible to say whether the sequence of events postulated here actually happened, but it is certainly plausible, and certainly more probable than the sudden appearance of a mysterious DeForest Type 20 tube advertised for only one month in May of 1920, followed by an equally mysterious disappearance without a trace or a single remaining artifact bearing a Type 20 designation, only to reemerge as a DV-6 look-alike three years later in mid-1923.

Fig.20. The mysterious "De Forest 20" tube appearing in the May issues of East Coast radio magazines may have referred to a soft version of this DeForest VT-21 manufactured for the U.S. Signal Corps during WWI.

Quite apart from the DeForest 20 conundrum, these early ads placed by the Pacific Radio Supplies Company were significant because they signaled to the radio community in general and to RCA in particular that Moorhead Laboratories was not going to cease operations simply because Marconi cancelled their agreements with Moorhead and DeForest. These ads also documented the methodology by which Shaw planned to market and distribute Moorhead Labs' tubes. Beginning in June of 1920, ads for Moorhead Labs listed the Atlantic Radio Supplies Co. of New Jersey as the Eastern Agent for Moorhead tubes—replacing Otis Moorhead's Pacific Laboratories Sales Department, which up this point had served as the sales agent for Moorhead Labs. Shaw's ads, which matured over the next few months, appeared regularly in many magazines, but none quite so prominently as those on the front pages of *Pacific Radio News* in multiple colors for several years to come (see Fig. 21). The Atlantic Radio Supplies Co. and Pacific Radio Supplies Co. became co-distributors for Moorhead Laboratories, replacing the Pacific Radio Supplies Co., which was advertised as the sole distributor in June ads. The

Fig.21. Prominent ads for the A-P Vacuum Tube Combination by the Pacific and Atlantic Radio Supplies Companies similar to this one appeared regularly on the front pages of the *Pacific Radio News* during 1920 and 1921. (*PRN*, Sept 1920)

A-P trade name replaced the Moorhead name, and the two new tubes were advertised as the A-P Electron Relay and A-P Amplifier-Oscillator.

In addition to these ads, Shaw also prepared two different sales brochures intended for use by distributors and retailers that clearly show how he intended to market Moorhead tubes. The first brochure dating to May 1920 was entitled "The Moorhead Perfect Vacuum Tube Combination" that advertised three tubes, the Moorhead A-P Amplifier-Oscillator, the Moorhead Electron Relay, and the Moorhead Transmitting Tube (see Fig. 22). While the Transmitter Tube was not advertised in radio periodicals at the time, this brochure clearly indicated that Shaw intended to offer a full line of Moorhead tubes consisting of not only both soft and hard tubes for reception but also a higher power tube for transmission. A second brochure followed

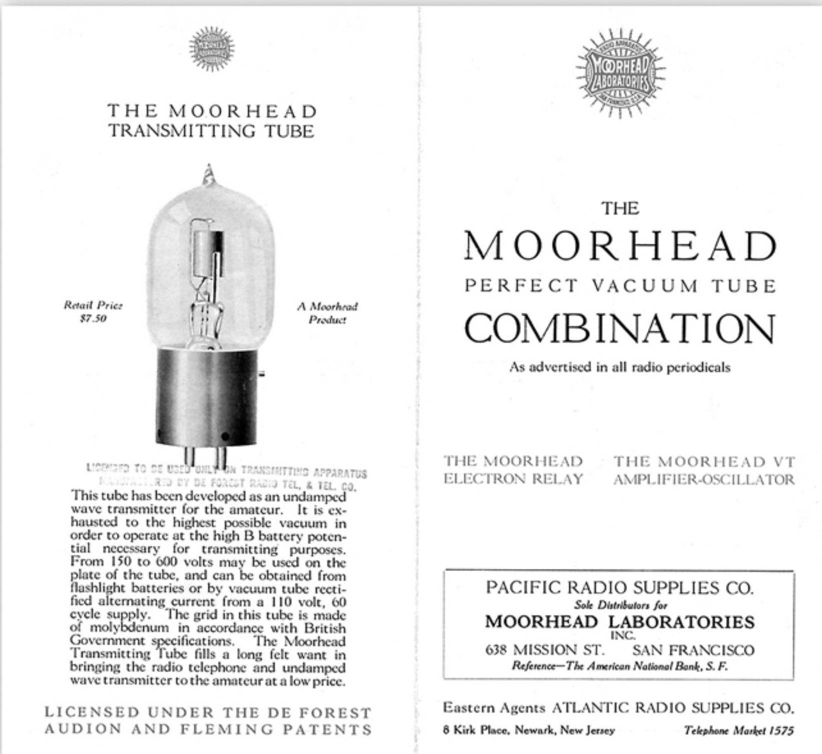


Fig.22. A Moorhead brochure distributed by Pacific Radio Supplies Co. dating to May 1920 pictured three of the tubes that Moorhead would make over the next two years: the Moorhead Transmitting Tube placed on the back side of the brochure, and the Electron Relay and VT Amplifier-Oscillator referenced on the front but appearing on the inside of the brochure.

in June entitled "The Atlantic and Pacific Vacuum Tube Combination" with the tag line "As advertised in all radio periodicals" (see Appendix B). This brochure was very similar to the first one with the notable exception that the Moorhead trade name was replaced by the "A-P" trade name. Thereafter, the Atlantic-Pacific Vacuum Tube designation appeared on the tube cartons used to package and distribute the tubes (see Fig. 23). It is also notable that this brochure has been found as an insert in the DeForest Catalog D along with a price sheet for other equipment dated July 1, 1920. Apparently the DeForest Company chose to continue selling the tube after the three party agreements had been terminated.

The hard tubes sold by Atlantic-Pacific Radio Supplies retained the V.T. and serial number stamps on the glass used by Marconi, but the soft Electron Relay tubes were stamped with E.R. and serial numbers that have been observed between 500,252 and 551,279. While the V.T. tubes sold by Atlantic-Pacific looked just like the image in its ads, the E.R. tubes never did. Ads for the E.R. pictured a plate structure with dimensions similar to Moorhead's prewar tubular Electron Relay (see Appendix B). However, while the early E.R. tubes had a cylindrical aluminum plate structure having dimensions similar to that shown in the ads, the actual tubes utilized a support structure consisting of tabs bent down against the press that did not appear in the ads (see Fig. 24). After the first 4,000 or so tubes, the mica spacer that appears in this photo was added to the top of the next 7,000 or so tubes for additional stability. After the first 11,000 or so E.R. tubes were manufactured, the height of the cylindrical plate was halved, the mica spacer was removed, and the plate and grid materials were changed to nickel (see Fig. 25). Despite these changes in the design of the E.R., none was reflected in the ads, which continued with the same original drawing of the tube throughout its entire production. None of the E.R. tubes was stamped with Moorhead Laboratories or A-P on the glass, but later E.R. tubes with serial numbers above ~525,000 were stamped on the brass base with the Marconi globe logo, the DeForest name, and patent information. For more information on the construction details of the E.R. and all other Moorhead tubes, see Condon's tube articles.

It would seem that RCA had a clear-cut case against Pacific Radio Supplies Company and/or Moorhead Laboratories, and could have taken legal action to close them down at the end of July

Fig.23. The Atlantic-Pacific Vacuum Tube designation appeared on tube cartons that were used to distribute tubes manufactured by Moorhead Labs. (Joe Knight Collection)

Fig.24. The earlier postwar E.R. tubes had a tall cylindrical plate similar to the prewar unbased tubular Electron Relay but with a support consisting of tabs bent down against the press, tabs which do not appear in post-war ads or brochures (the version shown here also has a mica spacer at the top).

Fig.25. E.R. tubes with serial numbers greater than ~511,000 had a cylindrical plate about half the height of earlier E.R. tubes.

when the cancellation of the June 6, 1919 agreements became effective. However, RCA's experience with Cunningham in its failed attempt to stop him from selling AudioTron tubes earlier in 1920 made RCA more circumspect about taking legal action against Moorhead Labs in the California courts. Instead, they pursued a different strategy that unfolded over a painfully long two-year period with many twists and turns, an intriguing story that is related in the remainder of this article.

RCA Responds to Moorhead Marketing

Even before Shaw first placed ads for Moorhead tubes in national radio magazines, RCA with its extensive spy network came across "literature relating to the Moorhead Vacuum Bulb." A memo from Sheffield & Betts to

Samuel Knight, Esq. at Marconi dated March 31, 1920 describes a brochure that may be the one mentioned earlier that was published in conjunction with the ad appearing in the March 1919 issue of *Electrical Experimenter*. RCA management was uncertain whether this brochure had been distributed just after it licensed Moorhead under the Fleming patent on Nov. 20, 1918, or redistributed in response to the cancellation notice dated January 30, 1920. RCA did not have to wait long to discover Moorhead's true intentions, which were clearly signaled by the flood of ads appearing in the May issues of nationally distributed radio magazines. RCA had one of its operatives posing as a small distributor respond to an ad in a May 1920 magazine by asking for particulars, and immediately received the brochure entitled "The Moorhead Perfect Vacuum Tube Combination" pictured in Fig. 22. Clearly, this brochure initiated several immediate and simultaneous actions over the course of the next four months, the results of which are of some note. First, RCA requested its law firm Sheffield & Betts to notify Moorhead Laboratories it was infringing on both Fleming and DeForest patents and demand they cease immediately. Sheffield and Betts sent the cease and desist letter on June 15, 1920, but neither Shaw nor Moorhead responded to it. Most interestingly, RCA arranged to have several tubes purchased directly from the Atlantic Radio Supplies Co. in order to check the serial numbers to determine if the tubes had passed through the RCA/DeForest distribution network pursuant to the three-part agreement, in which case they would have been licensed. The serial numbers on the first two of these tubes, Nos. 200,610 and 202,110 were found on orders shipped from Moorhead to RCA through DeForest. While both tubes did have the Marconi globe and the appropriate license information stamped on the brass base, neither had the restrictive legend "sold for amateur and experimental use only," which was stamped on the glass of all tubes delivered to RCA with this range of serial numbers. Further, tube No. 202,110 was reported as burned out and returned to DeForest. Additional purchases were made from Moorhead distributors with the same result, leading RCA to conclude that Moorhead was stamping multiple tubes with the same serial number in an attempt to hide the fact they were producing tubes outside the three-party agreements. This deception must have occurred on a grand scale because, according to David Sarnoff's testimony at the FTC hearings,[53] Moorhead made from 150,000 to 200,000 tubes—up to twice as many tubes than would be indicated from the serial numbers reported in the Condon/Jensby data base (see Appendix A).

Finally, Sheffield and Betts had suggested that RCA monitor the sales of Moorhead tubes in the New York City area, and in late September or early October of 1920, Elmer Bucher of RCA reported back that "practically everyone was selling them and that it was likely to interfere seriously with the marketing of the new tubes by the Radio

Corporation." In this regard, RCA was about to introduce their new line of Radiotrons in December 1920. Sheffield and Betts arranged to have inquiries made in the City, the results of which indicated that most of the major reputable supply companies such as Bunnell & Co., Manhattan Electrical Supply Co., Continental Radio and Electric Co., and Pacent Electric Co. were all selling Moorhead Amplifier-Oscillator, Electron Relay and Transmitter Tubes for between $6.00 and 7.50, depending on tube type. It would come out in later testimony that Sheffield and Betts had been writing letters in this time frame on behalf of RCA to major retailers threatening litigation for selling Moorhead tubes believed to infringe on both the Fleming and DeForest patents.

RCA Licenses Moorhead Labs

Henry Shaw had ignored Sheffield and Betts' cease-and-desist letter of June 15, 1920 for a number of months, but he finally decided to contact Marconi and arranged a conference with David Sarnoff on October 15, 1920 for purposes of settling the disagreements between the two Companies. Perhaps the warning letters Sheffield and Betts had been sending to Moorhead retailers were having some effect. There is no direct record of what transpired at the conference, but Shaw sent a letter to Sarnoff dated October 15, 1920, the same day as the conference, in which he stated his case and made several offers. Shaw began by stating that he had been operating the company from April 1, 1920 for the benefit of all creditors, and then requested the cooperation of RCA to assist in distributing the assets of the company after all liabilities had been provided for, suggesting two options for doing so: 1) Marconi could cooperate with Moorhead in disposing of enough tubes to pay off the debts of the company, which amounted to $150,000, or 2) Marconi could place an order and take deliveries until such time all debts were paid. Shaw wanted to sell the 20,000 tubes he had in stock (those which were made for the order Marconi placed in December 1919 and cancelled in January or February 1920) and manufacture an additional 50,000 tubes for sale in order to pay off all debts. Finally, Shaw requested that Marconi extend a license to Moorhead so it could continue selling tubes that might be "manufactured thru and by the Marconi interests."

Shaw followed this letter with a second letter dated October 30, 1920 with a specific request to receive "permission and recognition under the Fleming license patents to manufacture, sell and receive payment therefrom, to the extent of 35,000 vacuum tubes and your co-operation in removing all restrictions in the way of advertising matter and intimidation to purchasers, with the explicit understanding that the sale and financial returns accruing from the quantity above referred are to go towards liquidating legitimate debts of the Moorhead Laboratories of San Francisco, and that a royalty of 60¢ per tube payable to the Radio Corporation shall be made." Shaw then stated: "It is further understood that the Moorhead laboratories will cease all manufacturing, advertising and selling of vacuum tubes after the quantity above referred to is completed."

Any decision regarding licensing of vacuum tubes required the approval of not only RCA but also GE, AT&T and even Elmer Cunningham, who had an agreement with RCA that it would not grant licenses to others on more favorable terms than were granted to him. The pros and cons of licensing Shaw and Moorhead in lieu of bringing legal action were discussed at great length among RCA, GE and AT&T for several months. The cons of suing were fourfold. First, RCA would have to sue Moorhead and Shaw in the San Francisco court, where RCA had been unsuccessful in obtaining an injunction against Cunningham under the Fleming patent earlier in 1920 for selling his AudioTron. Second, if the litigation became protracted, Moorhead could sell a large number of tubes over the lengthy period of the trial, thus impacting the sales of RCA's tubes, which was scheduled to begin in December of 1920. Third, even if RCA were to prevail, the profits from the sale of Moorhead tubes during the litigation would be distributed to the creditors, in which case RCA could not recover damages, much less the substantial litigation costs. Fourth, Betts alluded to the possibility that RCA might have some liability to creditors for damages caused by suddenly cancelling the order for 20,000 tubes, which had been manufactured specifically at the request of RCA. The pros were that the license to Moorhead Labs would limit the total number of tubes sold to the public to 35,000, RCA would receive $37,500 in royalties from these sales, and Moorhead would voluntarily withdraw from the tube market.

While RCA, GE and AT&T were debating the pros and cons of granting Moorhead Labs a license, Shaw approved the introduction of the A-P Transmitting Tube, which first appeared in ads placed in the December 1920 issues of *Pacific Radio News, QST and Radio News* (see Fig. 26). Marconi had originally ordered a Moorhead transmitting tube designated Type C for a radiotelephone system it was developing for Cuba but never offered it for sale to the public. A similar transmitting tube designated the "Moorhead Transmitting Tube" had appeared in the Moorhead brochures of May and June of 1920 mentioned previously, but was not actually offered to the public at that time. This A-P tube with a stated capacity of about 12.5 watts was advertised as "a transmitting tube for telephone and telegraph C-W transmissions…" The ad further stated, "…any number may be used in parallel—four make telephone conversation possible over 25 miles, telegraph signals over 50 miles." While this tube had the designation T.T. stamped on the glass envelope, the numeral 2 was also inked on the press (see Fig. 27). This marking would indicate that it was nothing more than a V.T. tube, perhaps with a higher than normal vacuum, which would have allowed higher voltages to be applied to the plate. This contention is supported

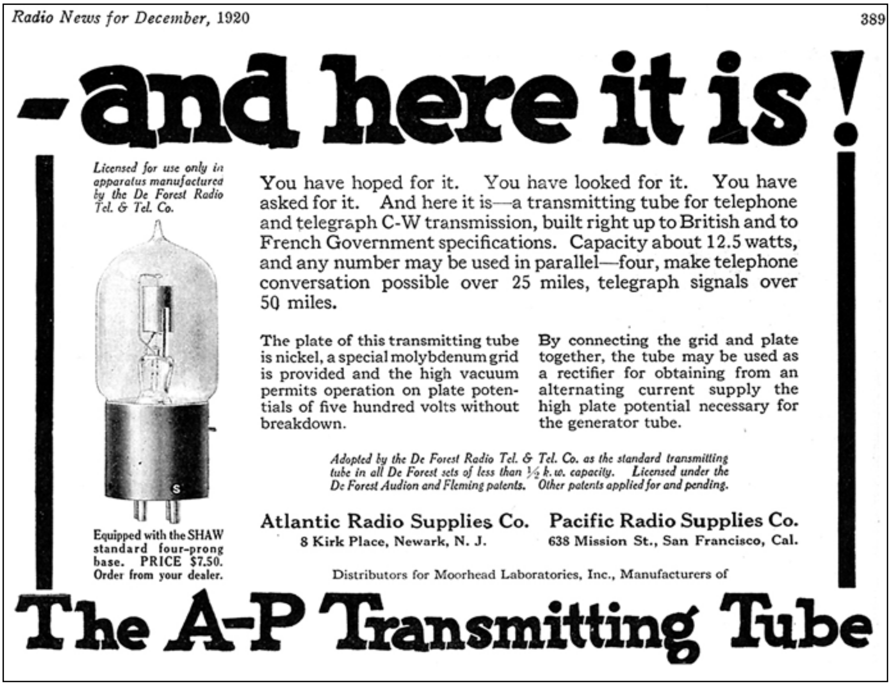


Fig.26. The A-P Transmitting Tube for telephony and telegraphy with continuous-wave transmission was introduced in December 1920 radio magazines. (*Radio News*, Dec. 1920, p. 389)

by the serial number 223,174 stamped on this tube, which is well within the range of serial numbers assigned to other V.T. amplifier-oscillator tubes manufactured at this time.

The RCA group finally decided to grant a license to Moorhead Labs in early January 1921 and directed Sheffield and Betts to prepare a draft of the license agreement. By that time, Shaw admitted that he had manufactured all of the 35,000 tubes to be covered by the license and had already sold 10,000 of them. Thus, the draft of the license agreement dated Jan. 25, 1921 stated these facts in the preamble, and the draft was written accordingly. The pertinent terms of the license were as follows: 1) the license was limited to the sale of twenty-five thousand (25,000) tubes or bulbs heretofore manufactured by the licensee and which have not been sold by the said licensee, 2) the tubes, cartons and advertising materials were to be properly marked with the Fleming and DeForest patent numbers and dates, and the following inscription: "Licensed only for amateur or experimental uses in radio communication. Any other use will be an infringement of above patents," 3) Moorhead was to pay a $1-per-tube royalty at the time of signing for the 10,000 tubes already sold, amounting to $10,000, 4) Moorhead was to pay $1.00 per tube "on each and every one of the remainder of said

Fig.27. While this transmitting tube was stamped with T.T. on the glass, the numeral 2 inked on the press and the serial number of 223,174 stamped on the bulb indicate that it is most likely an ordinary V.T. tube with a higher than normal vacuum.

twenty-five thousand (25,000) bulbs sold or otherwise disposed of by Moorhead for said uses under this license, and 5) Moorhead was to produce a monthly accounting for the number of tubes sold accompanied by the royalty payment specified for all tubes sold in the previous 30 days. It should be noted that since all 35,000 tubes to be sold under this license had been manufactured as of the date of the draft contract, there was no provision for manufacturing any tubes in this license. So, contrary to other historical accounts, the license was limited to selling 25,000 tubes—not manufacturing and selling 35,000. Also, while Shaw had promised in his letter to cease manufacturing, advertising and selling tubes after disposing of the remaining 25,000 tubes, there was no recital of such a promise or requirement to do so anywhere in the license document.

Shaw Becomes a Cunning Adversary

What happened from this point onward is a most interesting story that has never been chronicled. It will be seen that Shaw as president of Moorhead Labs was a cunning, if not duplicitous adversary, who was always two steps ahead of Sarnoff and RCA. To begin with, on Jan. 19, 1921, Shaw received an unsigned copy of a draft license agreement dated Jan. 25, 1921 for his review. While the draft contract specified that Shaw was to pay $10,000 in royalties for the 10,000 tubes already sold at the time of the signing, Shaw claimed he did not have enough cash to pay RCA, and so he arranged for RCA to accept $10,000 worth of equipment or materials in lieu of cash. While RCA was arranging a visit the Moorhead factory to select $10,000 worth of equipment or materials, Shaw signed two copies of the contract and returned them to RCA on Jan. 27, 1921 for their signature. He then placed an article in the *San Francisco Chronicle* entitled "Moorhead Co. Closes Contract with Marconi, G.E., and AT&T,"[54] which of course was not true—not only because the contract had not yet been signed, but also because the contract was with RCA and not any of the other companies named. RCA had warned Shaw "not to burst into print" with the unsigned contract, but he did so anyway, obviously to increase speculation on Moorhead Labs stock.

While RCA was chagrined by Shaw's article, Sarnoff decided not to confront Shaw, and instead pressed Shaw for the $10,000 worth of equipment or materials to satisfy the initial royalty payment so the contract could be signed as quickly as possible. However, Shaw had other ideas and was successful in stalling RCA's efforts to proceed, first by resisting RCA's insistence on obtaining $10,000 worth of manufacturing equipment rather than materiel so that Moorhead could continue to manufacture tubes. After settling on $10,000 worth of tungsten wire as a royalty payment, Shaw arranged to cause postponements of appointments with RCA representatives to inspect and value the tungsten wire at Moorhead Labs. Shaw then failed to provide clear title to the tungsten wire by delaying a payoff of two chattel mortgages on the tungsten wire. It was not until May 17, 1921 that Moorhead finally delivered to GE an amount of tungsten wire worth $10,000 (approximately a million feet) in lieu of cash with an unencumbered title to the material. All the while, Moorhead was manufacturing and selling tubes as fast as possible.

The contract was then ready to sign in May, but Sarnoff insisted on Shaw fulfilling two conditions that he claimed Shaw had agreed to previously, namely the removal of apparatus from the Moorhead plant to assure that no more tubes could be made, and an accounting for all tubes sold by Moorhead Labs since January of 1920. Shaw contested both conditions, thereby further stalling the closing of the contract. A meeting was arranged on June 23, 1921 between Shaw and Sarnoff in an attempt to resolve the outstanding issues. At this meeting Shaw claimed he had been deceived by Moorhead personnel and that Moorhead Labs had not actually manufactured 35,000 tubes yet, nor had they sold 10,000 tubes at the time the draft contract had been prepared in January. Shaw then claimed that more tubes had to be manufactured, not only to reach the agreed limit of 35,000 tubes but also to allow for replacements of rejected tubes. (There was nothing in the contract requiring Moorhead Labs to divest itself of manufacturing equipment, but Shaw had promised to do so in a letter leading up to the contract.) Shaw further claimed that accounting for additional tubes above the 10,000 was not required by the contract until after the contract was signed, which was true. Shaw asserted that any subsequent delay in signing the contract would not be his fault, and that he would fight any patent infringement suit brought by RCA. In the end, RCA signed the contract on July 1, 1921 without obtaining any concessions from Shaw.

While Shaw and Sarnoff were squabbling over the details of the license, Shaw introduced a new A-P Rectifier Tube, which appeared in ads such as the one shown in Fig. 28 beginning in May 1921 issues of selected radio magazines. The tube would allow experimenters to inexpensively generate 350, 500 or

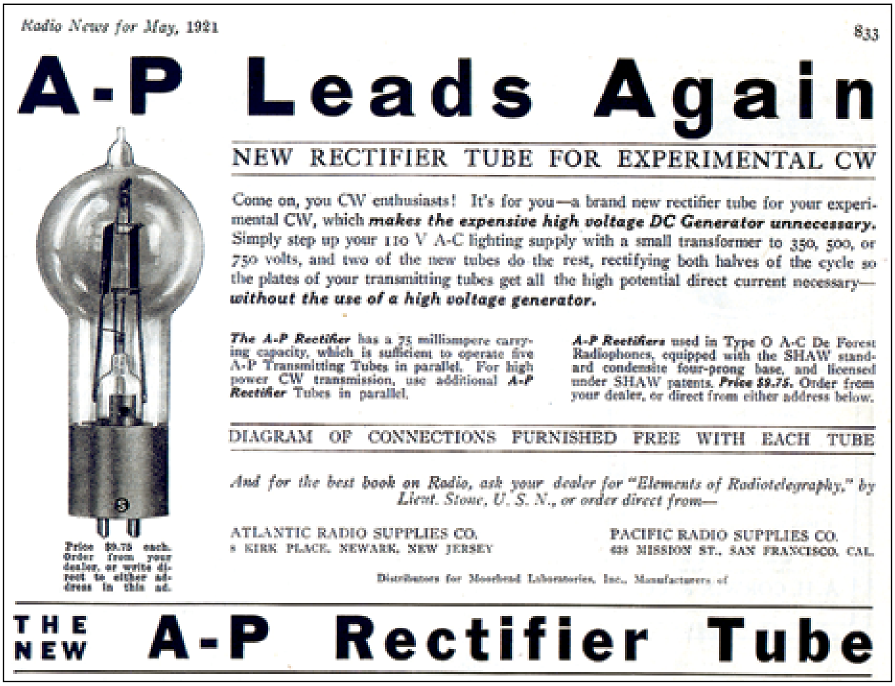


Fig.28. The A-P rectifier tube was introduced in May 1921 to allow experimenters to generate high-voltage DC from 110-volt A-C lines for use in CW transmitters. (*Radio News*, f. cover)

750 volts DC for use in CW transmitters by stepping up 110-volt A-C lines with a transformer and then rectifying it. The ad further stated that these tubes were used in the Type "O" A-C DeForest Radiotelephones. However, the tube pictured in the ad is clearly not a power rectifier because the plates are too far from the filament for efficient high-power rectification. The tube in the ad actually looks just like a DeForest Singer Power Oscillator/Amplifier Triode introduced in 1917, but with a Shaw base. The DeForest triode with the Shaw base that appeared circa 1920–21 is shown on the left of Fig. 29 with a widely spaced plate, and the A-P rectifier offered but not appearing in the ad is shown on the right with a closely spaced plate. The Shaw bases on both these tubes made of brass have identical license legends with "DeForest Audion" followed by the two DeForest patent numbers and a statement that it is for use by amateurs and experimenters use only. Such a legend on the rectifier is somewhat remarkable because as a rectifier it did not infringe on the DeForest patent, and as a *low-frequency* rectifier it did not infringe on the Fleming diode patent, for which a disclaimer had been filed on applications at low frequencies.

Henry Shaw testified at the FTC hearings that Moorhead manufactured both types of tubes.[55] After affirming that Moorhead made the two-element

Fig.29. The A-P Rectifier tube appearing in A-P ads looked more like the DeForest Singer Power Triode with a Shaw base (left) than the actual A-P Rectifier tube (right). (Stew Oliver and E. Wenaas collections)

A-P rectifier tubes, he was asked if he manufactured power tubes for transmitting purposes. Shaw answered, "We did for a short period and I stopped that. We were making the transmitting tubes for DeForest and I communicated the fact to the authorities here in New York, the AT&T, Mr. Betts, and refused to be entangled in the matter any further and stopped the making—that is, I gave the instructions, and no more were made because I dismantled the machinery and junked it." Thus, it appears that Moorhead Labs made not only the A-P rectifier tube, but also a version of the DeForest Singer tube with a Shaw base.

For the six-month period following the signing of the contract on July 1, 1921, there were no substantive interactions between RCA and Shaw or Moorhead Labs. The only notable event occurring during this period was the creation of a new company with the name Atlantic-Pacific Radio Supplies Co., which was incorporated under the laws of California on August 31, 1921.[56] (The Atlantic-Pacific Radio Supplies Company name will often be referred to hereinafter as A-P Radio Supplies.) The following announcement appeared in the first ad placed by this new company in the October 1921 issue of the *Pacific Radio News*: "In addition to national distribution of A-P tubes, manufactured by Moorhead Laboratories, Inc., the ATLANTIC-PACIFIC RADIO SUPPLIES COMPANY has recently secured exclusive Pacific Coast distribution of the following firms and lines:..." The following companies were then listed: DeForest Radio Tel. & Tel. Co, Diamond State Fibre Co., Shaw Insulator Co., and Redmanol Chemical Products Co. This announcement signaled a new direction for the company as representatives and sales agents for other manufacturers of radio and electrical equipment in addition to distribution of A-P tubes made by Moorhead Labs.

The next recorded interaction between the two companies was a letter from Moorhead Labs to RCA in early February 1922 reporting sales of 6,333 tubes for the two months of December 1921 and January 1922, accompanied by a royalty check for $6,333. At this sales rate, Shaw could have sold all 35,000 tubes allowed under the agreement in 1921 alone. However, as of March 1922, Moorhead Labs had accounted for sales of only 25,000 of the 35,000 tubes. Shortly thereafter, A. G. Davis, VP of GE, sent a telegram to David Sarnoff dated March 21, 1922 stating: "C. W. Stone telegraphs from San Francisco he is informed that Moorhead Laboratories are manufacturing and selling one thousand radio tubes per day. Think you should hasten your investigation and act promptly." Sarnoff responded in part by stating: "The Moorhead Company has thus far accounted and paid royalty for 25,000 out of the 35,000 tubes which they were authorized under the contract to sell. There is not the slightest question in my mind that they could have sold the remaining 10,000 tubes many times over."

Sarnoff began to strategize with attorneys Sheffield and Betts on how to "clean up the Moorhead situation by terminating all business relations with them." Since RCA had granted Moorhead a license to sell tubes, it could not bring suit unless it could be proved that Moorhead Labs had actually violated the terms of the license by exceeding their quota of tubes. To this end, Elmer Cunningham assisted RCA by engaging the Burns Detective Agency to have a woman secure employment with the Moorhead Laboratories and act as an undercover agent to gather the necessary data on how many tubes were being manufactured there. It was mid-April of 1922 by the time the woman secured employment, gathered information that Moorhead had indeed manufactured significantly more tubes than were specified in the license, and signed the necessary affidavit that would accompany the filing of the suit. The affidavit and several tubes Cunningham had arranged to purchase at the offices of A-P Radio Supplies Co. were sent to RCA attorney L. F. H. Betts who was preparing the lawsuit.

RCA Sues Moorhead, A-P Radio Supplies, et al.

In the end, RCA decided to bring a suit against Moorhead Labs and A-P Radio Supplies for infringement under the Fleming patent rather than breach of contract—in part because AT&T signaled that it would also bring suit under the DeForest patent, and in part to preclude Moorhead from asserting the doctrine of laches, which might allow them to avoid paying damages for infringement by asserting it was they who were actually damaged by Marconi's unreasonable delay in bringing suit. RCA filed its suit on April 24, 1922,[57] but in the end AT&T refused to bring suit because they did not want to participate in a suit for purposes of establishing a patent monopoly in vacuum tubes in view of the fact that AT&T itself was a wire monopoly.

As luck would have it, only four days after RCA filed its suit against Moorhead, AT&T obtained an injunction against Elman Myers and Radio Audion in Judge Van Fleet's court in San Francisco on April 28, 1922 for infringing the DeForest patent, which would prevent them from manufacturing or marketing the RAC-3 tubes for any purpose whatsoever.[58] This very positive result prompted the management of AT&T to change its mind about suing Moorhead, and two weeks later on May 9, 1922, AT&T filed suit against Moorhead, Shaw, et al. in the same San Francisco court alleging infringement of the DeForest patents.[59] On May 11, 1922, Willard Williamson acting as an attorney for all defendants wrote a letter to L. F. H. Betts informing him that the directors of both companies had removed Henry Shaw as a director and president and elected Willis M. Deming as president and manager of both companies. Williamson stated in FTC testimony that after Shaw departed he saw for the first time that the license RCA had given to Moorhead limited sales to 35,000 tubes. He further testified that Shaw had misrepresented this fact to the Directors, and that "a much larger number [of tubes] had been manufactured and sold by Mr. Shaw during his presidency."[60] This contention was supported by C. C. Langevin, the then A-P Radio Supplies sales manager, who testified that there were a very large number of tubes on backorder at the time they discontinued operations: "Yes, if I remember figures correctly, orders for something like 120,000 tubes. To put that conservatively we will say 100,000, which I am sure is within the narrow limits of correctness."[61]

The injunction under the RCA suit for infringement of the Fleming patent was prepared and consented to by all defendants as of May 23, 1922, although they had 60 days to file responses. The injunction under the AT&T suit for infringement of the DeForest patents had yet to be prepared, but all defendants agreed to cease manufacturing and sales even though the final injunctions had not yet been issued by Judge Van Fleet. All employees involved in the production of tubes (approximately 26) were dismissed on May 19, 1922, and production ceased. Permanent injunctions were eventually issued against all defendants including A-P Radio Supplies, Moorhead Labs and key individuals.

There is no record that either RCA or AT&T made an effort to have a court-ordered accounting of the number of tubes made by Moorhead with the idea of recovering damages for infringements. However, Sarnoff testified at the FTC hearings that he believed Moorhead made from 150,000 to 200,000 tubes under the auspices of the Marconi and RCA contracts. The number of tubes that Sarnoff cites in his FTC testimony is in line with an estimate made here using the known production rates and dates at Moorhead Labs. First, during the 6½-month period from mid-June 1919 to the end of December 1919, it is known from RCA documents that Moorhead Labs delivered approximately 36,600 tubes to RCA, amounting to an average production rate of ~5,500 tubes per month. This estimate is consistent with that of W. F. Williamson, a director of Moorhead Labs beginning in 1920, who confirmed that during 1921 Moorhead manufactured from 200–300 tubes per day, which would have amounted to 5,000–7,500 tubes for a 25-day work month.[62] If the demonstrated production rate of 5,500 tubes per month had persisted for the 26-month period from April 1, 1921 when Shaw reopened Moorhead Labs until the end of May 1922 when production ceased, Moorhead would have produced a total of 143,000 tubes. Add to that the 36,600 authorized tubes manufactured for and delivered to Marconi in 1919, and the total number of tubes made by Moorhead under Marconi and RCA auspices comes to 179,600 tubes—right in the middle of the range posited by Sarnoff.

A-P Radio Supplies Co. Changes its Focus

In early June of 1922, Williamson came east to ask Sarnoff for a license under the Fleming and DeForest patents, but Sarnoff opposed the request. In a letter dated June 8, 1922 Sarnoff wrote to A. A. Isbell, RCA's San Francisco representative that he was "sick of the whole lot of them," and he was "against granting them a license for propagating their life in any way." RCA notified Williamson in early June that no license would be forthcoming, and without further production and sales of Moorhead tubes, revenues of the A-P Radio Supplies Co. dropped precipitously. Williamson testified that he then attempted to sell Moorhead Labs with all the equipment "to get out of the thing, if we could, and save our money…"[63] He said he approached Elmer Cunningham at Audiotron, David Sarnoff at RCA with Mr. Betts of Sheffield & Betts, and John Harbord, the then president of RCA, but none would consider buying the Company.

At the same time Williamson was on the East Coast attempting to sell the company, plans were afoot to vacate the Moorhead factory building at 638-640 Mission Street, presumably to cut costs. The move of A-P Radio Supplies was first chronicled in an ad placed in the August 1922 issue of *Radio* magazine, in which its new address of 646-650 Mission Street appeared—a warehouse just several doors up from the old address. Although there was never any public notice of Moorhead Labs moving, the new address for Moorhead Labs appearing in the 1923 edition of the Crocker-Langley Directory for San Francisco was also 648 Mission Street, the same address as that listed for A-P Radio Supplies.[64] The move by both companies surely would have reduced costs because the warehouse at 648 Mission St., which was built in 1906 and still exists to this day, was smaller than the Moorhead Labs building (see Fig. 30). Additional evidence that this move took place is the fact that the Moorhead factory at 638-640 Mission Street was rented out for office space to several different organizations and individuals beginning in mid-1922 and extending into 1926, when the building became the first San Francisco office of IBM.[65]

The A-P Radio Supplies Co. then decided to revitalize its business as a distributor of radio equipment other than vacuum tubes. Fruits of this effort were apparent in the full-page ad that appeared in the July 1922 issue of *Radio* magazine featuring "new A-P apparatus ready for delivery," namely the AP-2 and AP-5 radio receivers manufactured by Oard Radio Laboratories. Oard was its first major client since March 1922 when DeForest ceased to be a client.[66] A-P Radio Supplies expanded the line of Oard receivers it distributed though the end of 1922, at which time it advertised five different Oard receivers in two full-page ads in *Radio* magazine. The full-page ad in orange and black for the Oard Phantom Receptor on the front page of the September 1922 issue of *Radio* is particularly striking (see Appendix B). The Atlantic-Pacific Radio Supplies Co. arranged to have its full name engraved into the panels of these sets as sole agent for Oard (Fig. 31).

According to a confidential report dated Nov. 29, 1922 prepared by R. G. Dun & Company, the Atlantic-Pacific Radio Supplies Co. offered 1,500 shares of stock at $95 per share to raise approximately $135,000 in additional working capital "to enlarge

Fig.30. Atlantic-Pacific Radio Supplies and Moorhead Laboratories Companies moved several doors away circa August 1922 to this smaller building at 648 Mission Street building characterized at the time as a warehouse.

Fig.31. Atlantic-Pacific Radio Supplies Co. was the sole distributor for Oard Radio Laboratories as evidenced by the A-P Company name engraved on the front panel of this Phantom Radio Receptor. (Stew Oliver Collection)

and extend the manufacturing and wholesale distribution of radio supplies and equipment." According to one electrical journal, the Company "just sold an issue of $250,000 of capital stock for purposes of financing its 1923 expansion program which contemplated adding new radio lines to those the company is now distributing, greatly increasing the present sales force and adding an electrical department, which will act as a factory distributor for standard electrical merchandise."[67] Indeed, shortly thereafter other clients appeared in the Company's ads such as Cutler-Hammer Mfg. Co., Carter Radio Co. and Dayton Fan and Motor.

Otis Moorhead Creates Universal Radio Improvement Co.

While A-P Radio Supplies was busy expanding its electrical equipment distribution business, Otis Moorhead began work on a new tube, presumably one that would not infringe on the DeForest patents. On Nov. 11, 1922 Otis Moorhead placed an article in the *Alameda Times-Star* announcing the creation of a new company, the Universal Radio Improvement Company, for the purpose of manufacturing vacuum tubes in Alameda, CA.[68] It was probably no coincidence that Moorhead placed this article entitled "Local Inventors Perfect New Radio Tube" on Nov. 11, 1922, two days after the Fleming patent expired.

This article stated that plans for a new factory were being drawn, and that a new plant located on Encinal Avenue in Alameda, CA would be producing vacuum tubes at a rate of over 1,000 per day within thirty days. It was further stated that branch offices would be opened in San Francisco and Seattle. O. B. Moorhead was listed as President and I. W. Hubbard of the Mother Hubbard Radio Supply Company was listed as Secretary. Directors of the Company were listed as George K. Ford of San Francisco, R. Whitney of Seattle, F. I. Hubbard of Alameda, and O. B. Moorhead. It is notable that all directors of this company were different from the directors of Moorhead Labs and A-P Radio Supplies Companies, whose directors were the same. The assets of the new company were listed as contracts with Otis Moorhead and I. W. Hubbard, assigned patents and applications, and the private research laboratory of Otis Moorhead valued at $20,000. It is also notable that the Company did not list manufacturing equipment among its assets.

This article no doubt prompted RCA's law firm of Sheffield and Betts to request that Elmer Cunningham keep an eye on the activities of Otis

Moorhead, his new company and Moorhead Labs, and report back to the attorneys on a regular basis. In his first letter to attorney L. F. H. Betts dated Nov. 13, 1922—two days after the announcement of the Universal Radio Improvement Co.—Cunningham reported, "So far neither the Moorhead people nor the Atlantic Pacific Company have made a move to reopen their factory on vacuum tube production." He went on to report some comments made by representatives of Moorhead Labs and A-P Radio Supplies Co., "Their people are stating to the trade, however, that they will have a new A-P tube, using a coated filament. I assume this must be the tube which De Forest is planning to place on the market and they state that there will be three tubes, using 1-volt, 3-volt and 5-volt filaments respectively." Indeed, DeForest introduced the three new tubes, DV-1, DV-2 and DV-6, later in 1923 with the three different filament voltages cited in the letter.

Other sources also indicated that Moorhead Labs and A-P Radio Supplies were negotiating with DeForest for a license, the first being R. G. Dun & Co., which reported on the activities of the Atlantic Pacific Radio Supplies Co. dated Nov. 29, 1922, stating in part: "They are also in negotiation with the DeForest Radio and Telephone and Telegraph Company of New Jersey for a new license agreement covering the sale and manufacture of vacuum tubes which they hope to secure in the near future and at the present time claim to have orders for vacuum tubes to the amount of $250,000 unfilled."[69] The second is a letter from A-P Radio Supplies Sales Manager, C. C. Langevin, to its distributor, Electric Appliance, Co. dated Dec. 11, 1922, in which he stated that the Company couldn't fill a recent tube order because "interests controlling the patents…have so far refused to grant manufacturing licenses."

Cunningham reported on further activities in Moorhead's factory in Alameda in a letter to L. F. H. Betts dated Dec. 28, 1922. He stated that tubes were being manufactured in Alameda on a small scale: "O. B. Moorhead is undoubtedly manufacturing double filament tubular bulbs in Alameda…. His operations are on a small scale. I have already purchased a sample of the tube, but have not been able to obtain access to his factory…" Cunningham's description of this tube is interesting because it matches descriptions of the unbased tubular Electron Relay tubes that Moorhead made before the war, which also had double filaments. Unfortunately, Cunningham did not describe this tube in any more detail, so that it cannot be identified. In any event, these four documents suggest that Moorhead Labs and A-P Radio Supplies Co. in San Francisco were pursuing goals different from those of Otis Moorhead and his Universal Radio Improvement Co. in Alameda.

Moorhead's first newspaper article was soon followed by a second article approximately two months later entitled "Giant Radio Plant Comes to Alameda," which appeared on Jan. 22, 1923.[70] Much of this article repeated what was said in the first article, with the notable exception that in the first article it was stated that tubes would be produced at a rate of 1,000 tubes per day within 30 days, while this article stated: "At the present time the company is manufacturing an average of 1,000 vacuum tubes [per day]…" However, it is unlikely that Moorhead had set up any kind of production line by January 1923—and certainly not at a rate of 1,000 tubes per day. The previous article had stated that the equipment owned by the Universal Company was $20,000 of Otis Moorhead's private laboratory equipment—not the production equipment that belonged to Moorhead Labs.

On Feb. 1, 1923, less than two weeks after the second article was published, a brief announcement appeared in the *San Francisco Examiner* which stated in part: "Otis B. Moorhead, 30, president of the Universal Radio Improvement Company of Alameda, died early yesterday morning following an operation for an injury sustained a few days ago."[71] His death must have caused the rapid demise of his company because nothing more about this company has been found in the literature subsequent to his death, and no artifacts consisting of products, ads or literature have been found. Further, no record of the incorporation of this company was found in a recent search of the corporate archives of the Secretary of State of either California or Washington state. It may well be that Moorhead died before the company was even incorporated.

A-P Radio Supplies Co. Announces New Tubes

A few months after Moorhead's death, Cunningham sent a letter to L. F. H. Betts dated April 6, 1923 reporting tube development activities at Moorhead Labs: "Moorhead Laboratories have been carrying on development work on vacuum tubes and I have just seen a sample of a new vacuum tube produced by this Company and which they contemplate placing on the market. They are making the statement that they plan to place this tube on the market within thirty days. In view of the particular appearance of this tube, I doubt very much if their plans will materialize." It is likely that this tube described as having a "particular appearance" was the Solenoid tube that was invented by tube designer Henry K. Huppert, an engineer who had consulted for Moorhead Labs previously in 1917. Huppert filed an application for this tube on Jan. 19, 1923, which issued on Dec. 1, 1925 as U.S. patent No. 1,564,070 entitled "Radio Vacuum Tube." This new tube was an "external grid" tube in which the outer element was a spiral-wound coil that, unlike a conventional grid or previous external-grid tube designs, produced a magnetic field in the internal region where the electrons flow from the filament to the plate (see Fig. 32), whereas the conventional grid placed between the plate and filament produces an electrostatic field. This new arrangement not only avoided infringement of the internal-grid tube covered by the DeForest patents, but was also said to eliminate static.

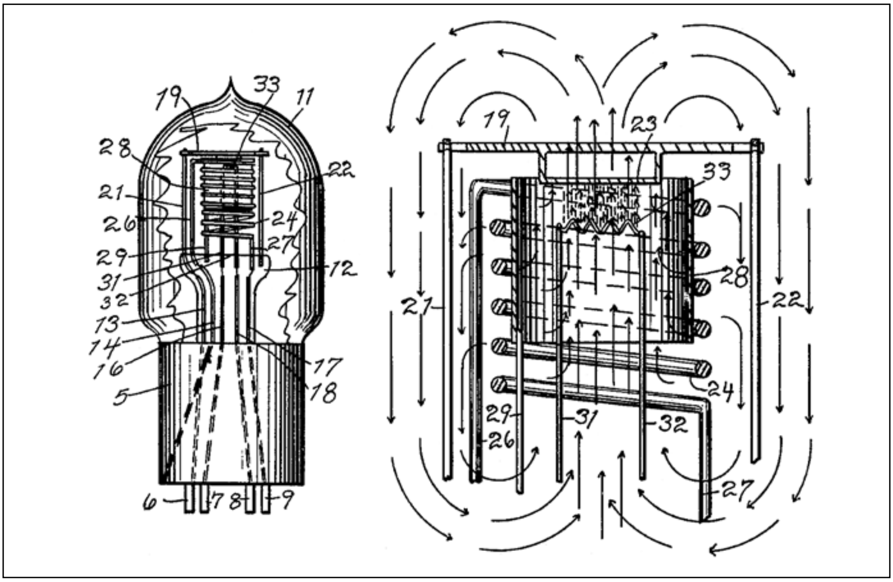


Fig.32. Henry K. Huppert used these figures with his U.S. Patent No. 1,564,070 to describe how the Solenoid tube functioned.

It is clear that Otis Moorhead was not involved in the development of this tube. In a letter from Frank A. Polkinghorn to Mrs. Robert A. (Jane) Morgan dated March 6, 1970 with recollections of his employment with A. P. Radio Laboratories (a company described in the last section of this paper), he clearly stated that Huppert did not become involved with Moorhead Labs until after Otis Moorhead died:[72] "Some time prior to the Spring of 1924 a man by the name of Huppert, a German who was an x-ray technician in partnership with a doctor in San Francisco, opened up a little shop and started making a few vacuum tubes. The machinery of the old Moorhead plant had been left in place awaiting the expiration of the fundamental DeForest patents in 1924. Shortly before they expired, Mr. Huppert got together with the Moorhead people (Moorhead himself had died some time before) and combined forces…" The shop mentioned by Polkinghorn was the Preston-Huppert X-Ray Laboratories located at 209 Post Street, less than one-half mile from Moorhead Laboratories.

Shorty after Cunningham wrote his letter dated April 6, 1923 describing a tube with a "particular" appearance, William W. Hanscomb, a local engineer and consultant, recorded a series of tests on a number of different designs of the "Huppert tube," as it was identified in his laboratory notebook. These tests performed between May and July of 1923 covered approximately 40 different design variations of the Huppert Solenoid tube. The prototype tubes described in his notebook had red and white stickers that were numbered and dated to correspond to the numbered and dated entries in his notebook (see Fig. 33). A number of tubes with these stickers can be found in the collections of tube collectors today. Presumably these tests were performed under the auspices of Moorhead Laboratories,

Fig.33. This Solenoid tube is one of forty prototypes tested by William W. Hanscomb between May and July 1923, each with a numbered sticker such as the one shown here with an 8 that corresponds to one of the forty different configurations numbered and documented in his laboratory notebook. (Stew Oliver collection)

not only because of the dates on the stickers but also because the brass bases have the same Marconi globe logo and DeForest patent information as many of the tubes Moorhead was manufacturing under the auspices of the RCA contract at the time. The results of these tests indicated that while the tube might be an improved detector capable of eliminating static, it did not function well as an amplifier or oscillator. These results must have been something of a disappointment to A-P Radio Supplies because it was clearly expecting to develop a complete line of tubes for all applications. In order to offer a complete line, the Company would have to develop another type of tube to function as an amplifier and oscillator, although on the positive side, this tube with an external grid would not infringe on the DeForest patents. The Moorhead Labs and A-P Radio Supplies Companies did not put the Solenoid tube into production at this time, possibly because of its technical shortcomings, but more likely because of financial problems.

Hanscom mentioned another interesting type of tube on a later page in his notebook dated Oct. 22, 1923 under the heading "Huppert Tubes," where he scribbled the following paragraph: "Brought in several new tubes made by him [Huppert] having thoriated filament and chemical exhaust [getter] with sodium mercury amalgam. It had 2 concentric 3 element structures mounted in parallel with one filament central thru both worked very well, equal to 201-A on 6 volts with .12 amps, "B" 35 volts. Good oscillation, sensitive and michrophonics [sic]…. In all above the elements were mounted vertically in std Moorhead tubes." The tubes to which Hanscom refers would become known as the Two-in-One tube that will be described in some detail at the end of this article.

There are several interesting points about this entry. First, the phrase "brought in" indicates this tube was designed and assembled by Huppert in his laboratory and not at the Moorhead facility. Second, it dates late October as the time frame when the tube had been designed and when Moorhead Labs and A-P Atlantic-Pacific Companies became acquainted with its performance. The time frame fits neatly with a letter that Elmer Cunningham wrote to L. F. H. Betts shortly thereafter dated Dec. 13, 1923 stating: "At a recent meeting of the local Radio Trade Association, the sales manager of the Moorhead, Atlantic-Pacific Companies made a public announcement that they would resume manufacture of vacuum tubes in January after the expiration of the DeForest patent… For some time these people have been talking about a new tube that they have and I have been fortunate in seeing a sample. It is a rather crude looking affair and really possesses no merit. I cannot state at this time whether they contemplate the manufacture of this special tube or a tube with a grid and plate on opposite sides of the filament. I am keeping in close touch with the situation and will advise you of any development."

Cunningham's letter and the Hanscom notebook entries are crucial to the understanding and interpretation of the events of 1923. First, it is clear that the crude looking tube referenced in Cunningham's letter is the Solenoid tube, and the second tube was what became known as the Two-in-One tube. Second, it is clear that neither tube was manufactured during the year 1923. Third, it indicates that the officers and directors of both Moorhead and A-P Radio Supplies were aware that the Two-in-One tube would infringe on the DeForest patent, but that they believed the controlling patent was the first DeForest patent scheduled to expire on Jan. 15, 1924 and that they would be safe in manufacturing the Two-in-One after that date. Apparently that was a common misconception at that time, as L. F. H. Betts pointed out in a response to Cunningham's letter of Dec. 13, 1923 with a letter of his own dated Dec. 19, 1923: "Other people evidently have the idea that when the first DeForest patent expires in January, 1924, the manufacture of vacuum tubes will be open, but of course you know as well as I do that the second DeForest patent, which does not expire until February, 1925, for the specific form of the three-element tube in which the grid is located between the filament and the plate, effectively controls the vacuum tube situation."

At some point in December 1923, the officers and directors of the Moorhead Labs and A-P Radio Supplies must have become aware that the second DeForest patent controlled the vacuum tube situation and that the Two-in-One tube would infringe that patent because they made a decision not to proceed with the manufacture of either tube as originally planned. Williamson, an experienced attorney, was probably the one who realized that if the two companies were to proceed with their plans to manufacture and market this tube in January of 1924, the Company and all associated parties who were under the injunction proscribing the manufacture and sales of tubes infringing on the second DeForest patent could be sanctioned quite severely by the Court with a simple motion filed by either RCA or AT&T.

In a surprise move, the directors of Moorhead Labs actually decided to terminate not only the vacuum tube business per se, but also to cease operations altogether. Corporate secretary Williamson testified at the FTC hearings that the directors allowed the charter of the Moorhead Laboratories to expire in January 1924, thereby dissolving the Company.[73] The A-P Radio Supplies Co. was also abandoned in January of 1924, although in a somewhat circuitous manner. Some historians believe that one or both of these companies were reorganized as the A-P Radio Laboratories but that is not so. The details of the disposition of Atlantic-Pacific Radio Supplies Co. follow.

Disposition of the Atlantic-Pacific Radio Supplies Co.

While A-P Radio Supplies Co. raised several hundred thousand dollars in January of 1923 to expand its sales force, it was not able to attract new clients with profitable product lines. Testimony from George A. Turner, President of the Portable Wireless Co., given at the FTC hearings revealed that sales of the Oard radio receiver line declined after the A-P Radio Supplies Co. was unable to provide tubes for the sets as a result of the manufacturing injunction in May 1922.[74] By May of 1923, the distribution of Oard products had declined substantially and they were regularly in arrears on payments to the Portable Wireless Co, who was actually the primary distributor for the Oard line and who consigned the Oard products to A-P Radio Supplies. All magazine ads with the A-P Radio Supplies Co. name suddenly stopped after May of 1923, and no further ads, notices or articles with the name have been found in any publication since that time. For all intents and purposes, the company vanished.

Actually, Company attorney W. F. Williamson filed an application for a name change to Atlantic-Pacific Sales Co. on May 9, 1923.[75] There was no announcement of the name change, there was no reason given, and no reason is apparent. A few references to the new Atlantic-Pacific Sales Co. name have been found in various radio magazines, indicating it actually did business under the new name,[76] although none of these references were display ads. The name change was never acknowledged in any of the correspondence found in RCA files; the company was simply referred to as the Atlantic-Pacific Company in correspondence during the last half of 1923.

The name change is pertinent only because it is a crucial link in following the corporate trail to determine the actual disposition of the Atlantic-Pacific Radio Supplies Company. The key to the puzzle is an announcement that appeared in the January 1924 *Journal of Electricity* which stated: "The Atlantic-Pacific Agencies Corporation has been organized to supersede and take over the business of the Atlantic-Pacific Sales Company, San Francisco, Calif. W. M. Deming is president; T. D. MacMullen is vice-president and C. C. Langevin secretary of the new company, which will represent many eastern manufacturers of electrical appliances, radio supplies, heating equipment, etc."[77] Deming and Langevin were associated with both of the previous A-P companies, but T. D. MacMullen was not. No reason was given for changing the name of the Company from Atlantic-Pacific Sales Co. to Atlantic-Pacific Agencies Corporation. However, the creation of a new legal entity would have provided legal separation from Atlantic-Pacific Companies in the event of future legal actions. Ads with the Atlantic-Pacific Agencies Corp. name appeared occasionally in radio magazines for a number of years as Pacific Coast representatives of eastern companies such as Hammarlund Mfg. Co.[78]

Thus ended the saga of Moorhead and his vacuum tubes. Moorhead Laboratories ceased to exist in January of 1924, as did its sales agency, which over the years had no fewer than five separate names: Pacific Laboratories Sales Dept., Pacific Radio Supplies Co., Atlantic Radio Supplies Co., Atlantic-Pacific Radio Supplies Co., and Atlantic-Pacific Sales Co. All that was left of the Moorhead empire was the manufacturing equipment, which was warehoused at 650 Mission Street, several doors away from the original Moorhead factory. The rights to the Solenoid and Two-in-One tubes apparently belonged to their inventor, H. K. Huppert.

Creation of A-P Radio Laboratories Co.

The story does not end with the demise of the Moorhead Labs and the Atlantic-Pacific Sales Company. It appears there was a grand scheme to have the two companies exit the business of manufacturing and distributing tubes by creating a completely separate entity for the purpose of manufacturing tubes, to which the existing equipment and material could be sold. Allowing the lapse of the Moorhead Labs' charter and suspending operations of the Atlantic-Pacific Sales Co., successor to the Atlantic-Pacific Supplies Company, were only the first two steps in such a scheme. The third step was to create an entirely new entity for purposes of manufacturing tubes, one in which none of the officers, directors or employees had any association with the old companies nor were they under the injunction issued in 1922.

W. F. Williamson must have been the architect of such a plan because he prepared the incorporation papers for the new A-P Radio Laboratories Co. that were duly filed on March 21, 1924. The stated purpose for this company in its Articles of Incorporation mimicked the stated purpose appearing in the Articles of Incorporation for the Atlantic-Pacific Radio Supplies Company that Williamson had filed a few years before on Aug. 31, 1921. Williamson must have picked the officers and directors because they were all prominent businessmen, bankers and/or investors from the San Francisco area, most of whom were also his friends, acquaintances or associates. The five directors were listed as H. J. Jepsen, E. Molkenbuhr, G. G. Vodvarka, A. S. Hutchinson, and T. M. Benson—none of whom were associated with any of the previous Moorhead-related companies. Williamson, as the attorney who filed for incorporation, selected Benson and Hutchinson as the incorporators, and also arranged for them to be directors. He also must have arranged for D. C. Seagrave to be president and D. E. Gunn to be Secretary because both were employees at the time of the filing. Other key employees were Henry Huppert who joined the company in 1924 and became the head of the manufacturing and sales departments on Feb. 1, 1925,[79] and Frank Polkinghorn, a prominent engineer, who joined the company in 1924 as its chief engineer in charge of tube design.

It is sometimes stated in the literature that the A-P Radio Laboratories was the successor to the Moorhead Laboratories,[80] but that is not true. The term "corporate successor" has the specific legal meaning that the successor corporation takes on the burdens of a previous corporation through merger, acquisition, or other means of succession. A-P Radio Laboratories was specifically structured so that there was no identifiable means of succession, and therefore neither the Company nor the officers and directors could be held accountable for infringing on DeForest and Fleming patents based on the injunction against Moorhead Labs, et. al.

In FTC testimony, D. E. Gunn, Secretary of A-P Radio Laboratories, revealed some other interesting information about the activities of the A-P Radio Labs during the 13-month period it manufactured tubes. First, the Company acquired the manufacturing equipment of Moorhead Labs from an unidentified trustee of the defunct Moorhead Company—which must have been none other than Williamson, who as Corporate Secretary for Moorhead Labs would have been responsible for liquidating Moorhead Labs assets. Second, when asked how the tubes were sold, Gunn testified that they were sold through a sales agent, which at first was Electric Appliance Company and later the Baker-Smith Company. In fact, no ads placed by A-P Radio Labs have been found in any of the literature where one might find these ads, but ads were placed by the Baker-Smith Company for Two-in-One tubes.[81] Gunn did say that two advertising circulars had been prepared and distributed, one of which has been found. When asked for the name of the tube that the Company was selling, he responded "Two-in-One." He was not asked if there were any other tubes sold by the company, and he did not mention anything about the sale of a Solenoid tube.

Gunn also testified that the company manufactured an average of 3,000 tubes per month until July 1925, at which time the company voluntarily ceased operations. However, he did not say anything about the time frames when each of the two tubes were sold. Thus, one can conclude that the Company manufactured approximately 39,000 tubes for the thirteen months that the company was in business, but one cannot conclude how many were A. P. Solenoid tubes and how many were Two-in-One tubes. Bill Condon, using serial number data, estimated that a total of about 2,000 Solenoid tubes were sold. Both tubes may have been sold simultaneously for the entire period, or the Solenoid tube may have been sold first, thereby delaying the point in time at which the infringing Two-in-One tube was sold, possibly to forestall legal action by either RCA or AT&T. It is interesting to note that Huppert wrote a feature article for *Hardware World* magazine describing the "new A-P 'Two-in-One' tube" and identifying its then-current distributor, Baker-Smith Co., which appeared in the February 1925 issue, the very month that the second DeForest patent expired.[82]

Gunn gave two reasons for the Company discontinuing business in July 1925, the principal one being that by early 1925 the retail price of tubes dropped to the point that it was no longer profitable for the Company to manufacture tubes. The other reason cited was the difficulty the Company had in obtaining filament material. While the Company stopped producing tubes in mid-1925, it was not until March 8, 1932 that the Company was suspended for reasons unknown—possibly for failure to file documents required in the normal course of business. This would have been an inexpensive way of going out of business without having to file dissolution papers.

Turning to the tubes themselves, the production version of the Solenoid tube was stamped on the glass with a serial number, the trade name "A-P Solenoid" and the phrase "Patents Pending" as shown in Fig. 34. There was no patent information stamped on the brass bases. Since the Solenoid tubes have already been described, only the Two-in-One tubes are addressed here. The Two-in-One tubes were just that—two triodes wired in parallel within a single envelope for the purpose of increasing the power output (see Fig. 35). Many articles of the day were written about the advantages of wiring two tubes in parallel. An A-P Radio Laboratories sales brochure published in early 1925 stated the Two-in-One tube would produce more power without distortion and promised that replacing the amplifier tubes in a receiver would mean "less effort to bring in distant stations—greater clarity—easier tuning—greater efficiency of your set."

The two triodes in the Two-in-One tube were contained within two cylindrical structures that formed the plates, which were oriented vertically within the glass bulb and attached together lengthwise as shown in the cutaway sketch of Fig. 36. Spiral-wound grids were placed in each of the cylindrical plates and connected together so they

Fig.34. This tube with serial number 962, A-P Solenoid and Patents Pending stamped on the glass was one of approximately 2000 production tubes sold by A-P Laboratories. (Joe Knight collection)

Fig.35. The Two-in-One tube consisted of two triodes enclosed within a single glass envelope (removed).

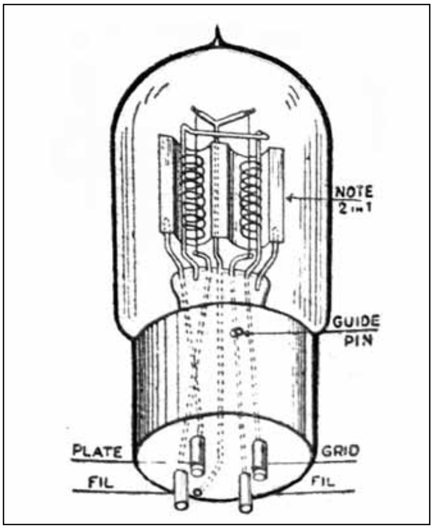


Fig.36. A cutaway sketch of the Two-in-One tube illustrates two vertically oriented cylindrical plates in contact with each other containing spiral-wound grids that are connected together at the top allowing the two triodes to act in parallel. (Two-in-One Brochure, courtesy of Joe Gruber)

acted in concert. A single filament ran up from a pin in the base, through the center of the grid in one cylinder to the top, over a "Y"-shaped support to the other cylinder, and then down through the other grid to a second pin in the base. A special lead was brought out from a center tap of the filament at the midpoint along the top and connected to the metallic base of the tube without going through either cylinder. Thus, the base of the tube constituted a fifth electrode. With this center tap, the filament could be connected in series or in parallel and could be operated on either 3 or 6 volts.

The 1925 A-P Radio Labs brochure shows four different Two-in-One tube types: Type 625A amplifier, Type 625D detector, and two other tubes, No. 306A with a standard base and No. 306P with a UV-199 base. Sketches of two tubes appearing in the brochure are reproduced in Fig. 37. A tube stamped 306M with the UV-199 base has also been observed (see Fig. 38). The detector tube was described as a gassy version of the amplifier tube, and the brochure warned the user that the amplifiers should not be used as detectors or the tube will "over-sensitize the set and make it microphonic."

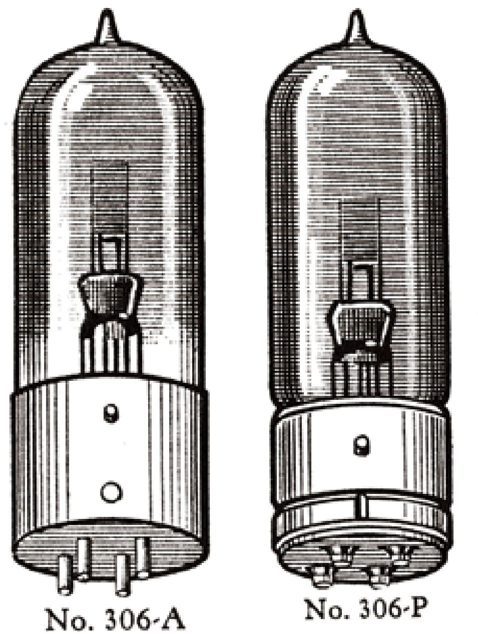


Fig.37. A brochure distributed by the A-P Radio Laboratories pictured sketches of a 306-A tube with a standard base and a 306-P tube with a UV-199 base. (Two-in-One Brochure, Courtesy of Joe Gruber)

Fig.38. This 306-M tube with a UV-199 base was not mentioned in the A-P Radio Laboratories brochure. (Joe Knight collection)

Moorhead Equipment Sold to Q R S Music Co.

As mentioned previously, D. E. Gunn testified that A-P Radio Labs voluntarily ceased operations in July of 1925. According to letters by Frank Polkinghorn, the Q R S Music Company bought the equipment and patents from A-P Radio Laboratories as an asset purchase shortly after they ceased operations.[83] According to Q R S Music employee R. O. Ford, Q R S Music manufactured tubes in the A-P Radio Labs factory at 650 Mission Street for about a year before he assisted in moving the equipment to a modern Q R S factory building located at Seventh and Folsom.[84] The Redtop tubes manufactured at the time by Q R S Music had the same double-triode construction as the Two-in-One, but the Redtop (also spelled "Red Top" by Q R S) actually had a pedigree that can be traced back to the Radio Essentials Corporation taken over by Q R S Music about the time A-P Radio Labs ceased operation.[85] The Radio Essentials Corporation filed for the Redtop trademark on Apr. 24, 1925, for which the Corporation claimed first usage on Feb. 13, 1925.[86] Whether the original Redtop tube designed by the Radio Essentials Corporation had the double-triode configuration at the time of the asset purchase from A-P Radio Labs or whether it was added after the asset purchase from A-P Radio Labs is not known. In either event, Q R S had no real connection to A-P Radio Labs other than the fact they bought the manufacturing equipment from the defunct A-P Radio Labs Company.

Endnotes

1. E. P. Wenaas, "E. T. Cunningham and the Vacuum-Tube Tangle," *The AWA Review*, Vol. 25, 2012, pp. 185–251.
2. E. P. Wenaas, "Part II: Elman B. Myers and the Vacuum-Tube Tangle," *The AWA Review*, Vol. 26, 2013, pp. 37–94.
3. "New Electrical Developments, San Francisco, Ca," *J. of Elect.*, Vol. 40, No. 12, Jan. 1, 1918, p. 648.
4. *Moorhead and His Valve*, published by Moorhead Laboratories, Aug. 1919, p 9.
5. O. B. Moorhead and E. C. Lange, "The Specifications and Characteristics of Moorhead Vacuum Valves," *Proc. IRE*, Vol. 9, No. 2, Apr. 1921, p. 95–129.
6. Bill Condon, "Moorhead and His Tubes," *Tube Collector*, Vol. 5, No. 2, Apr. 2003; Bill Condon website address: http://www.bill01a.com/.
7. R. Bown, "War Time Development of Vacuum Tubes," *Elect. World*, Vol. 73, Feb. 22, 1919, p. 359.
8. *Moorhead and His Valve*, p. 22; also H. H. MacDonald, "Inventor Moorhead Reports Company Financial Position," *San Francisco Chronicle*, Sept. 14, 1919, p. C10.
9. *Ibid.*, p. 21.
10. *Radio Case, Federal Trade Commission vs. General Electric Company, American Telephone & Telegraph Company, Western Electric Company Inc., Westinghouse Electric & Manufacturing Company, The International Radio Telegraph Company, United Fruit Company, Wireless Specialty Apparatus Company, and Radio Corporation of America*, (Sidney C. Ormaby Company, 217 Broadway, New York, 1928) pp. 2186. This document is referred to hereafter as "FTC Hearings, 1928."

11. "Marconi – Moorhead Agreement of November 30, 1918."
12. These two agreements were described in some detail in Part I and Part II.
13. FTC Hearings, 1928, p. 1575. This suit was also reported in the San Francisco newspapers: "Patent Tangle Lawsuit Opens," *S. F. Chron.*, Apr. 30, 1919, p. 8.
14. "Moorhead Laboratories," *S. F. Chron*, May 1, 1919, p. 20.
15. "Marconi – Moorhead Inc. & Otis Moorhead License Agreement of April 30, 1919.
16. The term "agency" was a common term of the day meaning a representative as well as a distributor.
17. "Moorhead, Inc. & Otis Moorhead – Marconi Agency Agreement Contract of April 30, 1919."
18. "Marconi – Moorhead Laboratories & Otis Moorhead License Agreement of June 6, 1919."
19. "DeForest – Moorhead Agreement of June 6, 1919."
20. "DeForest – Marconi Agency Agreement of June 6, 1919."
21. "Radio Vacuum-Tube Litigation is Settled," *Elect. World*, Vol. 73. No. 25, June 21, 1919, p. 1349; also see *Radio News*, Vol. 1, No. 2, Aug. 1919, p. 77.
22. "The Marconi V. T.—A Three-Electrode Oscillation Detector of Approved Operating Characteristics," *Wireless Age*, Vol. 6, No. 11, Aug. 1919, pp. 33–34.
23. AudioTron Sales Co. Display Ad, *Everyday Engineering*, Vol. 7, No. 3, June 1919, p. 187.
24. Display Ad, *Wireless Age*, Vol. 6, No. 10, July 1919, p. 45.
25. Karl E. Hassel, "An Audion Warning," *QST*, Vol. 3, No. 1, Sept. 1919, pp. 28–29.
26. "The Radio Department," *Everyday Engineering Mag.*, Vol. 7, No. 5, Aug. 1919, p. 298.
27. E. M. Sargent, "Crystal and Vacuum Tube Detectors," *Radio Amateur News*, Vol. 1, No. 7, Jan. 1920, p. 355–356.
28. M. L. Snyder, "Notes On Vacuum Tubes," *Wireless Age*, Vol. 1, No. 10, Aug. 1923, pp. 68–69.
29. Will Jensby in a private communication provided a majority of the observed serial number data, which consists of Moorhead tube data sheets for approximately 300 Moorhead tubes collected by Jensby and Bill Condon from the mid-1980s to Aug. 10, 1984, the date on the data log sheet. Data from an additional forty tubes in the authors collection were also used.
30. One tube without A or B markings on the glass but with a 1 inked on the press (indicating it was a soft tube) has been observed with S/N 10,241—clearly an outlier that has been omitted to avoid skewing the distribution.
31. "Instruction for Testing SE-1444 Vacuum Tubes Built on Contract 45217," U.S. Navy Yard, Washington, Apr. 8, 1919.
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About the Author

Eric P. Wenaas has had a lifelong passion for antique radios beginning with his first Radiola and crystal set given to him as a young man growing up in Chicago by family friends. He experimented with radio devices and repaired radios and televisions as a hobby while in high school, and went on to study electrical engineering at Purdue University, graduating with B.S. and M.S. degrees in Electrical Engineering. He then went to the State University of New York (SUNY) at Buffalo where he earned a Ph.D. degree in Interdisciplinary Studies in the School of Engineering. After graduating, he spent most of his career at Jaycor, a defense company in Southern California—first as an engineer and later as the President and Chief Executive Officer.

Upon his retirement in 2002, he set out to research the early days of wireless and document interesting historical vignettes based on original documents of the era. He has written numerous articles for the *AWA Review*, the *AWA Journal* and the *Antique Radio Classified*, and published a critically acclaimed book in 2007, *Radiola: The Golden Age of RCA - 1919–1929*, covering the early history of RCA—including the formative years of the Marconi Telegraph Company of America. For this work, he received the AWA Houck Award for Documentation in 2007. He received a second Houck Award in 2012 for His Work in Preserving the History of the Radiola by his Outstanding Collection. Dr. Wenaas is a lifetime member of the AWA and a past member of both the IEEE and the American Physical Society. He resides in Southern California and continues to enjoy collecting radios, researching the early days of wireless and writing articles.

Eric P. Wenaas

Appendix A: Serial Numbers

The purpose of this appendix is to reinterpret the Moorhead serial number data base in light of RCA and Marconi documents that suggest Moorhead Labs manufactured many more tubes than historians have inferred from this data base. A thesis of this article is that Moorhead Labs under Henry Shaw's tutelage duplicated serial numbers on a grand scale in an attempt to hide the large numbers of tubes manufactured outside the scope of Marconi and RCA license agreements. The database examined here with over 300 entries was provided by Will Jensby; it was supplemented by 40 Moorhead tubes from the author's collection. The database consists of serial numbers, bulb stampings, bulb shape, color of the glass, markings on brass bases, press material, press letters and numerals, and other notes.

Estimates Assuming No Duplication

First, an estimate of the number of tubes manufactured in quantity for Marconi will be made based on serial number data in the Jensby/Condon database assuming no duplication of serial numbers. These numbers will be compared with the known number of tubes ordered and received by Marconi on the three contracts it had with Moorhead. Table A-1 has been created to summarize the serial number data for these four tubes, arranged according to the three Moorhead contracts with Marconi and RCA. The first column lists the three contracts, the first two being for 10,000 tubes and 20,000 tubes respectively under the three-party agreements with Marconi signed June 6, 1919, and the third under the auspices of the contract with RCA dated Jan. 25, 1921 permitting Moorhead to

Moorhead Contract	Tube Types	S/N Ranges Observed	No. from S/N Data	No. per Contract
Three-Party Contract 1	Class A	168-5,941	6,000	5,000
	Class B	223-2,856[1]	3,000	5,000
Three-Party Contract 2	Class A	200,065-207,184	7,400[2]	16,600[3]
	V.T.[2]	207,185-215,214	9,200	
	Class B	100,141-109,846	10,000	10,000
RCA 1921 Contract	V.T.	216,601-247,180	30,579	35,000
	ER	500,252-551,279	51,300	
		Total	117,479	71,600

[1] Condon reported S/N 10,241, an outlier that has been omitted to prevent skewing.
[2] Tube marking changed from A to V.T. between S/N 207,184 and 207,547
[3] 6,600 V.T. tubes added under Contract 2 to replace A and B rejects

Table A-1: Serial Numbers Arranged by Moorhead Contracts sell 35,000 additional tubes. The second column identifies the four tube types manufactured in large quantities (A, B, V.T. and E.R.). The third column contains serial number data grouped according to the contract under which each type was manufactured, the fourth column is an estimate of the number of tubes manufactured deduced from the serial number data assuming no duplications, and the fifth column is the number of tubes authorized under each of the three contracts according to documents in RCA and Marconi files. The serial numbers and quantities deduced here are rounded and/or interpolated, and therefore are approximate. The following notes further explain entries in the table.

Marconi Contract 1: Type A and B tubes must have been numbered separately because there are no numbers above 5,941 for either Type. The serial numbers indicate that 6,000 Type A tubes and 3,000 Type B tubes were manufactured under Contract 1, although Marconi documents clearly state there were 5,000 of each. Marconi files also state that 950 SE-1444 tubes were initially received, processed and sold as Type A, which means the serial number data agrees with Marconi documents that approximately 10,000 tubes were manufactured under Contract 1. While there is a minor discrepancy in the number of soft versus hard tubes, it is known that some of the hard tubes that Marconi found gassy at 100 volts were sold as soft tubes.

Marconi Contract 2: Approximately 16,600 tubes were delivered under Contract 2 including the 20,000 soft and hard tubes originally ordered plus another 6,600 hard tubes delivered to replace all tubes rejected under both contracts. The soft tubes observed under the second contract had serial numbers between 100,000 and ~110,000, and were stamped with the letter B. All hard tubes had serial numbers of the form 2xx,xxx, and the first 7,400 or so were stamped with the letter A. The remaining 9,200 hard tubes delivered under the second contract were stamped with V.T. and would have had serial numbers up to ~216,600. The highest observed serial number in the database that would have been manufactured under the second contract is 215,214.

RCA Contract dated Jan. 25, 1921: The remaining hard tubes marked V.T. with serial numbers above ~216,000 were sold by Marconi under the auspices of this contract with RCA, as were all soft E.R. tubes with serial numbers observed between 500,252 and 551,279. The fact that these tubes were sold under the auspices of the RCA contract does not mean they were all authorized.

The conclusion from this table is that while 71,600 tubes were authorized under the three contracts, the available serial number data indicate that at least 117,479 tubes were made—approximately 45,879 tubes more than were authorized. All of the unauthorized tubes were made under the auspices of the RCA agreement dated Jan. 25, 1920, which authorized only 35,000 tubes.

Evidence of Duplication of Serial Numbers

While RCA found duplications in serial numbers by comparing newly purchased tubes with its entire database documenting the disposition of each tube, no duplication appears in the Jensby/Condon Moorhead tube database supplemented by the authors database. This is not surprising because the chances of finding even a single duplicate in a random sample of 300-350 tubes out of total population of 150,000 to 200,000 is less than 1%. However, there are two markers in the serial number database that indicate the serial numbers were duplicated, perhaps the most obvious being in the database of hard tubes from Contract 2—that is, Type A and V.T. tubes with serial numbers of the form 2xx,xxx.

One marker indicating duplication of serial numbers is the patent legends on the brass base of the tubes, which do not uniformly appear on all these tubes—contrary to what RCA documents clearly state. According to RCA documents, all 16,600 hard tubes delivered to RCA under the second contract had Shaw brass bases with the DeForest name and patent information on one side and the Marconi globe logo on the other as shown in Fig. 39. This base is referred to hereinafter as a "D/M base." Also, Marconi had ordered an additional 20,000 V.T. tubes from Moorhead in December 1919 that should have had the same D/M legends. (While these tubes were never delivered, Henry Shaw testified that Moorhead manufactured these 20,000 tubes for RCA with hopes that RCA would accept them, and so they were almost certainly manufactured with D/M stamped brass bases to satisfy RCA requirements.) Thus, all tubes with serial numbers from 200,000 to 236,000 should have the D/M stamp. However, this expectation is inconsistent with the database, which reveals that only about half the tubes in this range have the D/M stamp, and that they are interleaved with bases that do not (see Table A-2).

In order to quantify the interleaving, the serial numbers are grouped together in Column 1 according to how many *consecutive* samples in the database are the same—either with or without a D/M stamp. For example, the first tube in the database (S/N 200200) has only one consecutive D/M base mark, the next two tubes in the database (200249 & 200289) have no D/M base

Fig.39. The Shaw brass base characterized in the text as a "D/M base" had the Marconi globe logo and Fleming patent number shown here stamped on one side, and the DeForest name and patent information stamped on the opposite side.

	Sample (SMP) S/N Range	Base Mark	SMP Size	S/N Range	SMP/ 1000
Tube Type "A"	200200	D/M	1	6984	3.1
	200249-200289	--	2		
	200420-200530	D/M	2		
	200830	--	1		
	201477-201694	D/M	3		
	201848-202417	--	3		
	202609	D/M	1		
	203469-205246	--	6		
	206453-207184	D/M	3		
Tube Type "V. T."	207547-2088xx	D/M	4	16065	2.2
	209061-209932	--	3		
	210713-210965	D/M	2		
	211684-213045	--	2		
	213067-213348	D/M	2		
	213520-213908	--	3		
	214255	D/M	1		
	215001	--	1		
	215124	D/M	1		
	216644	--	1		
	217318-221113	D/M	5		
	221252	--	1		
	221696	D/M	1		
	222187-222589	--	3		
	222827-223222	D/M	2		
	223400	--	1		
	223468	D/M	1		
	223604-223612	--	2		
	227242-243900	D/M	15	16658	0.9
	245561	--	1	1493	2.7
	245573	D/M	1		
	246589	--	1		
	247054	D/M	1		

*Bases with Marconi logo and DeForest licensing

Table A-2: Serial Number Analysis for Type A and V.T. tubes

mark, the next two tubes have the D/M base mark, and so on all the way down the column (ignoring the horizontal lines for the moment). The number of consecutive samples with like base marks (either with or without the D/M stamp) is recorded in Column 3.

What is immediately obvious is that with one exception, there are no large runs of consecutive serial numbers with the D/M base mark, contrary to what would be expected from the RCA documents. It appears that bases without the D/M mark were interleaved in a relatively uniform manner with bases having the D/M mark, which is indicated by the small size of the groups that have the same consecutive mark. There is one exception to the small sizes of consecutive samples with the like base marks, namely the 15 consecutive samples with serial numbers between 227242 and 243900 representing a population of 16,658 tubes, all of which have the D/M mark. One can infer that there was no interleaving in this portion of the population—and this portion only. The chances that 15 consecutive base marks (either with or without the D/M mark) would be drawn randomly from a population of bases half with and half without base marks is approximately one out of 2^{n-1} where n is the number of consecutive samples, which in this case would be 1 in 16,384. (Compare this with the chances of having 6 identical consecutive samples, namely one in 32, the same as the number of number of sample groups in the table.) Since roughly half the tubes have the D/M base mark and half do not (excluding the group with 15 consecutive D/M marks), one can infer that an equal number of tubes with base marks were interleaved with tubes without base marks—except in the range of 16,658 tubes, which is represented by the sample size of 15 tubes where no interleaving is apparent.

Another marker that can be used to quantify the degree of duplication of serial numbers is the difference in the *density* of tubes samples that would be collected for a group where interleaving occurred as compared to the density where interleaving did not occur. For purposes of this analysis, the S/N database is first divided into two groups for purposes of comparison—the Type A and Type V.T. The Type V.T. is further subdivided into three groups—the group of 15 represented by the shading in the table where interleaving does not appear and the two groups with serial numbers above and below the group of 15. The total number of tube samples represented in the table is 77, and the sample sizes for the four groups listed in the third column are 22, 36, 15 and 4 respectively.

Assuming the tubes in the database were collected randomly, there would be more tubes collected in a given range of serial numbers for the groups that were interleaved as compared to the group of 15 not interleaved. The density of samples in any selected group is simply the number of tube samples in the group divided by the range of serial numbers for tubes in the group, which is expressed in Column 5 as samples per thousand tubes (SMP/1000).

Beginning with the first group consisting of all Type A tubes, the lowest serial number is 200,200, the highest is 207,184 and the total range for this group is 6,984, which is registered in Column 4. The total number of samples of tubes in the Type A group is 22 (sum of the Type A sample numbers in Column 3), and the density of tube samples is therefore 22/6,984 or 3.1 tube samples in the database per thousand tubes manufactured with serial numbers in this range. The same analysis is applied to the other three groups with the results shown in Column 4 of the table. It is obvious that all three groups that display interleaving have at least twice the sample density of the group of 15 that does not display interleaving.

The inescapable conclusion is that of the 47,054 tubes manufactured that are represented here by 77 samples, all but 16,658 tubes were interleaved with two populations of tubes sharing the same serial numbers—one with the D/M mark and one without the mark. To put it another way, it appears that Moorhead was able to hide the manufacture and sale of approximately 30,000 Type A and Type V.T. tubes by duplicating serial numbers. This conclusion would also explain the puzzle that Condon pointed out when he deduced from the sample sizes in this database that twice as many Type A tubes survived as Type B. While strictly speaking his conclusion is valid, the reason is almost certainly because twice as many Type A tubes were manufactured, not because Type A tubes were somehow more resilient.

The same analysis was applied to the E.R. tubes with the same result. It turns out the density of points for E.R. tubes with serial numbers between 500,252 and 519,971 is almost exactly twice that for all serial numbers above 519,971, indicating that 20,000 more E.R. tubes were manufactured than indicated by the serial number extrapolations shown in Table A1. Adding the estimated duplications of 30,000 tubes in Type A and 20,000 in Type E.R. to the total number of 117,479 tubes estimated without duplication from Table A1, Moorhead most likely manufactured at least 167,500 tubes, well within Sarnoff's estimate of 150,000 to 200,000.

Appendix B: A Retrospective of Moorhead Artifacts

A selection of surviving artifacts from the following companies associated with Otis B. Moorhead is presented here: Moorhead Laboratories, Atlantic and Pacific Radio Supply Companies, A-P Laboratories, and Q R S Music Company. The artifacts consist of vacuum tubes, tube cartons, instruction inserts, an ad and a factory-made receiver.

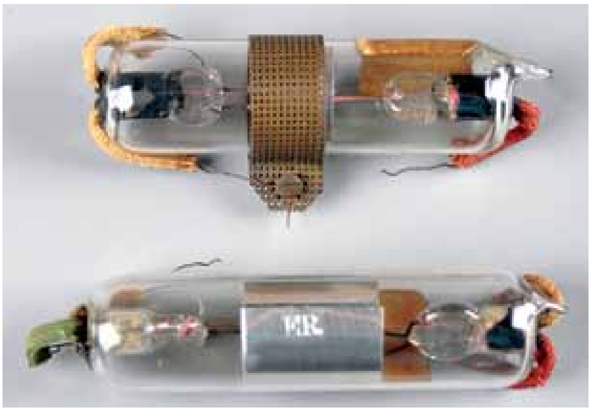


Fig.B1. **Moorhead Prewar Electron Relays:** Moorhead began to advertise the external-grid tube designated "Moorhead Tube" (top) in September 1916 as a replacement to the internal-grid Electron Relay tube (lower) because ads for the Electron Relay were rejected by all major radio magazines except for *Pacific Radio News* beginning in September 1916 due to threats of lawsuits by DeForest for selling tubes with internal grids that allegedly infringed DeForest patents. (Stew Oliver collection)

Fig.B2. **Moorhead Wartime Tubes**: During WWI Moorhead manufactured three tubes in quantity, the British Type B transmitting valve (left), the British Type R receiving valve (right), and the SE-1444 receiving audion for the U. S. Navy with a Shaw base (center). (Stew Oliver and author's collections)

Fig.B3. **Moorhead British Type B Variants**: Two variants of the British Type B manufactured by Moorhead are the Type B with a Shaw base believed to be a prototype made in small quantities (left), and the Type VT-32 with a tubular bulb made in quantity during and/or after the war (right). (Stew Oliver collection)

Fig.B4. **Moorhead Postwar Tubes Sold by Marconi**: The Moorhead hard A tube (left) and soft B tube (right) have the key physical characteristics of all Moorhead tubes sold by Marconi: either rounded cylindrical or spherical glass bulbs, either soft tubes with clear glass or hard tubes with or without a light-golden color getter coating, presses either with or without inking indicating tube type, and Shaw bases with or without the Marconi globe logo, DeForest name and patent information.

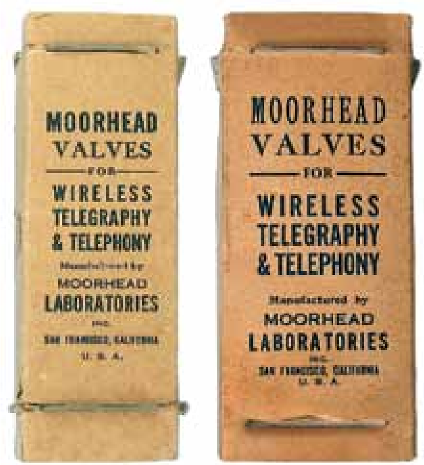


Fig.B5. **Early Moorhead Egg-Crate Cartons**: Moorhead packaged its wartime and postwar vacuum tubes in these “egg crate” cartons made by Wallace Egg Carrier Co. that came in two sizes, the narrower one on the left for cylindrical tubes, and the one on the right for spherical tubes with a larger diameter. (Stew Oliver collection)

Fig.B6. **Evolution of Marconi Egg-Crate Cartons**: Early Moorhead egg-crate cartons with glue-on labels were initially used for Marconi tubes (left) until a carton with the label information stamped onto the card-board became available (right). (Joe Knight and Stew Oliver collections)

Fig.B7. **Complete Marconi Tube Package**: The egg-crate cartons containing the V.T. tubes were placed into a larger box for shipping along with a single “notice” sheet and a 12-page brochure with characteristic curves, a preferred detection circuit, and cautions for operating the tube.

Fig.B8. **Tube Used Clandestinely by RCA?**: This tube with serial number 4250 stamped on the bulb and the unusual legend “PROPERTY OF RADIO CORPORATION OF AMERICA, NOT LICENSED FOR USE BY OTHERS” on the brass base may be one that was used clandestinely by RCA in its commercial work circa 1919-1920; note the blurred area on the left where the restriction “LICENSED FOR AMATEUR OR EXPERIMENTAL USE ONLY” was placed has been etched.

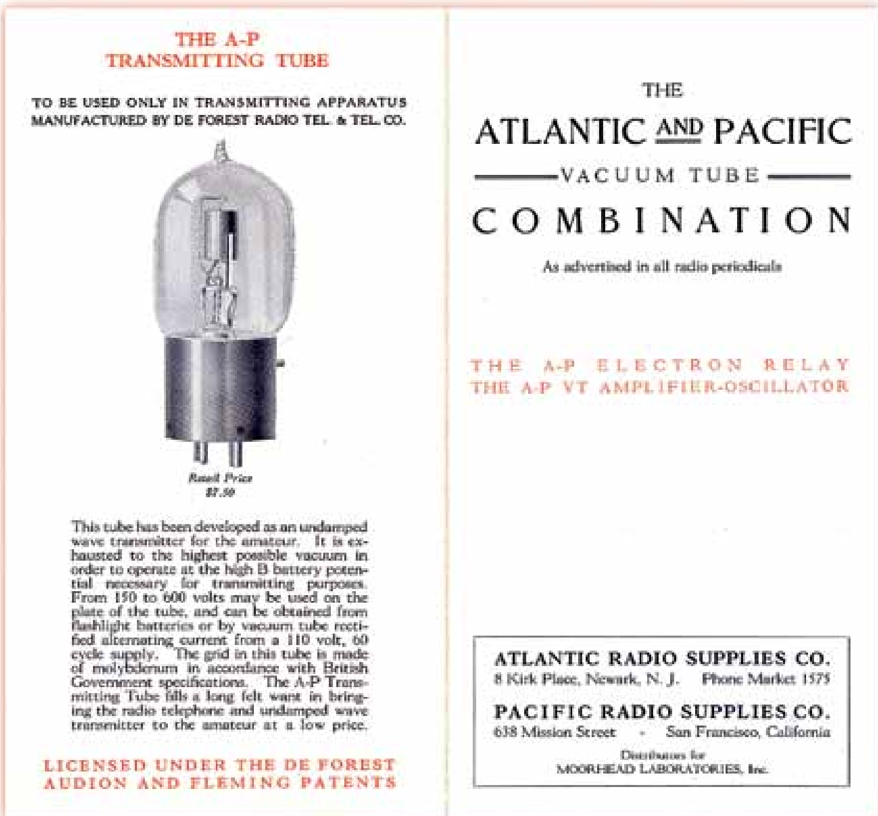


Fig.B9. **Atlantic and Pacific Combination Sales Brochure**: This brochure for the A-P Electron Relay, A-P VT Amplifier-Oscillator and A-P Transmitting Tube prepared by Atlantic and Pacific Radio Supplies Co. was found in the DeForest Catalog "D" distributed circa July 1, 1920; it replaced a similar brochure produced in May 1920—the primary difference being that the Moorhead trade name had been replaced by "A-P."

Fig.B10. **Atlantic and Pacific Radio Supplies Co. Packaging**: Immediately after Henry Shaw created the Pacific Radio Supply Co. in April 1920, new egg-crate tube cartons and packing boxes were produced for the Atlantic and Pacific Radio Supplies Companies—the new marketing and distribution organizations for tubes made by Moorhead Labs. (Joe Knight collection)

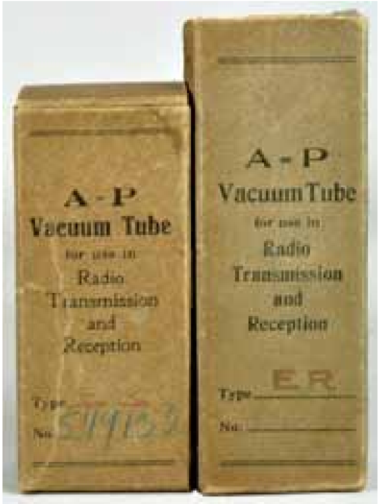


Fig.B11. **A-P Vacuum Tube Cartons**: The early double-box configuration using an internal egg-crate carton was replaced by a single-carton configuration labeled "A-P Vacuum Tube," the designation used in ads for all Moorhead tubes as of August 1920; two different carton lengths have been observed. (Joe Knight collection)

Fig. B12. **V.T. Tube with Duplicated Serial Number:** This V.T. tube with serial number 215,800 without patent legends on the glass or brass base is believed to be one of many tubes with a serial number duplicated by Moorhead Labs to mask the number of tubes purportedly manufactured under its contract with RCA dated Jan. 25, 1921.

Fig. B13. **Soft E.R. Tubes**: Soft E.R. detector tubes with Shaw bases introduced by Moorhead Labs in mid-1920 evolved from the prewar unbased Electron Relay; the earliest version had a spiral copper grid and a cylindrical aluminum plate with tabs extending down and bent against the press and (left), while later versions had a nickel grid and plate half the height of the earlier plate—one version of which was shiny (middle) and the other was black (right).

Fig. B14. **DeForest Singer Type Power Oscillator/Amplifier Triode**: According to Henry Shaw, Moorhead Labs manufactured this Singer Type Power Oscillator/Amplifier triode at DeForest's request; this was the tube that actually appeared in A-P ads beginning in May 1921 advertising an A-P Rectifier Tube without a grid.

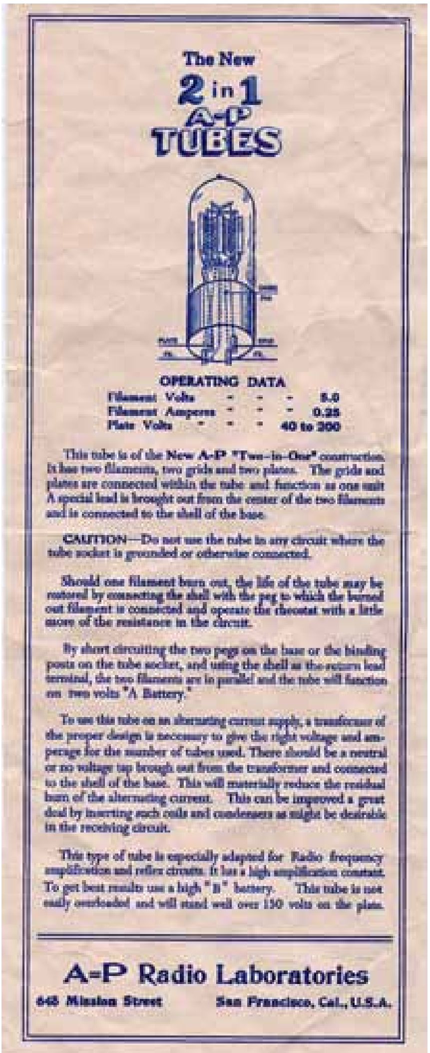
Fig.B15. **A-P Radio Supplies Ad**: The Atlantic-Pacific Radio Supplies Co. expanded its radio distribution business by introducing Oard Radio Laboratories equipment that appeared prominently in attractive ads in color on the front cover of many issues of *Radio* magazine such as this one for Oct. 1922.

Fig.B16. **Oard Phantom Radio Receptor**: The Atlantic-Pacific Radio Supplies Co. had an agreement with Oard to be its sole agent, an agreement that is memorialized by the inscriptions appearing on the front panels of Oard radio equipment such as this Model B Phantom Radio Receptor. (Stew Oliver collection)

Fig.B17. **Moorhead Prototype with Rectangular Plate**: This unusual triode tube with a nickel base marked "PAT PEND" is believed to be a Moorhead prototype with an upright rectangular plate structure open only at the top and bottom but not on the sides, a configuration that suggests it may have been intended to be a power amplifier tube made circa 1920.

Fig.B18. **Prototype Solenoid Tubes**: These two tubes with red labels identified by the numbers 7 and 8 (left to right) are two of forty different prototype solenoid tubes identified by number in the laboratory notebook of consultant William W. Hanscomb, who tested the tubes under the auspices of Atlantic-Pacific Sales Co. between May and July of 1923; note the difference in solenoid coil dimensions and material. (Joe Knight and Stew Oliver collections)

Fig.B19. **Two-in-One Tube with Carton**: The Two-in-One tube believed to be a Type 625A consists of two triodes wired in parallel within a single glass envelope that was manufactured by A-P Laboratories, a company that had purchased the assets of Moorhead Labs without becoming its legal successor. (Sonny Clutter collection)



The New
2 in 1
A-P
TUBES

OPERATING DATA

Filament Volts - - -	5.0
Filament Amperes - - -	0.25
Plate Volts - - -	40 to 200

This tube is of the New A-P "Two-in-One" construction. It has two filaments, two grids and two plates. The grids and plates are connected within the tube and function as one unit. A special lead is brought out from the center of the two filaments and is connected to the shell of the base.

CAUTION—Do not use the tube in any circuit where the tube socket is grounded or otherwise connected.

Should one filament burn out, the life of the tube may be restored by connecting the shell with the peg to which the burned out filament is connected and operate the rheostat with a little more of the resistance in the circuit.

By short circuiting the two pegs on the base or the binding posts on the tube socket, and using the shell as the return lead terminal, the two filaments are in parallel and the tube will function on two volts "A Battery."

To use this tube on an alternating current supply, a transformer of the proper design is necessary to give the right voltage and amperage for the number of tubes used. There should be a neutral or no voltage tap brough out from the transformer and connected to the shell of the base. This will materially reduce the residual hum of the alternating current. This can be improved a great deal by inserting such coils and condensers as might be desirable in the receiving circuit.

This type of tube is especially adapted for Radio frequency amplification and reflex circuits. It has a high amplification constant. To get best results use a high "B" battery. This tube is not easily overloaded and will stand well over 130 volts on the plate.

A-P Radio Laboratories
643 Mission Street San Francisco, Cal., U.S.A.

Fig.B20. **Two-in-One Instruction Insert**: This Two-in-One insert was reconstructed from a damaged insert found in a carton similar to the one in the previous figure. (Sonny Clutter radiolaguy@comcast.net)

Fig.B21. **Two-in-One 360M Tube with 306P Carton**: A-P Laboratories manufactured smaller versions of the Two-in-One tube with a base and electrical characteristics similar to the UV-199. (Joe Knight collection)

Fig.B22: **Q R S Redtop Tube with Carton**: A Q R S Redtop tube with two triodes in a single envelope similar to the Two-in-One tube was manufactured by the Q R S Music company circa 1925-6 using equipment it purchased from the defunct A-P Laboratories. (Sunny Clutter collection)

Strange to my American Eyes

Observations of broadcast receiver design features in greater Europe not seen in contemporary American design and some understandings as to why they are different.

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Abstract

It may be obvious to many people interested in the development of home broadcast receivers that cabinet designs, fabrication techniques and performance specifications can often be recognized as originating in a particular country or region of the world. I wanted to understand why such differences existed. While technical and advertising information is not too difficult to obtain, I rarely found direct references to socio-economic background information in searches. Having attained some notoriety in the style of exhibitions I have presented at various national and regional historical radio conferences, I was asked to present illustrated talks in 2012. The goal was to highlight design and fabrication differences from American practice and talk about why they were, or might have been, different. Developing these lines of inquiry has added new, interesting and challenging dimensions to my life long hobby. At the same time, it has provided me with an increased sense of purpose for preservation and documentation of these artifacts. This paper builds on the themes of these talks with the hope that the reader will be encouraged to include these lines of inquiry into their own activities.

I think I have heard over the years that the United States of America may be able to lay claim to fully half of all technical and design innovation in communications electronics in the first half of the 20th century. Most of us know that this is a huge industry that over time has employed hundreds of millions in invention, enterprise development, infrastructure development, engineering, manufacturing, distribution and marketing.

For a long time I have been aware that vintage radio construction methods have often been 'country specific'. i.e. An experienced collector can know almost immediately the country of origin. At some point I began to ask myself; why is that?

Having been a collector of American vintage home broadcast receivers since before 1967, sometime in the mid 1980's I met an Italian national, Vic Franzoni, working here in the US as a corporate representative of an Italian knitting machine manufacturer. While here in the US he became interested in collecting American home broadcast receivers and in many conversations over the years he became my conduit for information on radio manufacture in Europe. He returned to Italy but we maintained our friendship for close to 15 years and I began to trade American made radios with him for interesting European broadcast receivers.

My goal was to have a few representative models from the 1920s to the 1950s, and beyond if necessary, from each country that was known to have some sort of domestic home broadcast radio industry. While the basic circuitry concepts were well known here and abroad, the physical implementation could often be radically different. Not only could I collect something different looking, but I could also enjoy research to obtain an understanding of why these items were different than seen here. If my reasonably comprehensive collection of domestic radios was well formed by more than 30 years collecting, looking abroad was likely to provide a vast pool of new opportunities to acquire and learn about 'the other half'. One I'll not live long enough to complete. That's good!

Much of this difference between American and European design can surely be traced to the fact that the development of the commercially sponsored radio broadcasting model in America was a distinct anomaly to the broadcast model adopted in most of the rest of the world. Our model, as it developed in the 1920s, produced programming appealing to local audiences from local advertiser's market area and it seemed as if *everybody* wanted to get into the business. As time passed, it became possible to network radio stations to satisfy the advertising needs of national brands. It also made it possible to pump considerably more money into the development of programming that would attract tens of millions of families to invest in radio ownership even during the Great Depression.

Their alternative models were generally to have a state agency that not only managed the radio spectrum but actually was charged with operating broadcast facilities *and* producing content to be broadcast. This expense was paid for by the specific taxation of receiving equipment sales and annual licenses paid by the radio owner for the privilege of receiving the broadcasts. There are numerous articles in American radio magazines of the early 1920's debating the merits of both schemes.

In my state of North Carolina, the air miles between the eastern-most town, Manteo and the western-most town, Murphy is 474 miles. Using a similar distance arc around the city of Prague, Czech Republic has you touching on countries where more than 14 different languages are spoken. While beginning with small transmitters on Medium Wave near a few major cities; in many of their models, the financing scheme, population scales and prosperity levels of the general populace found it more logical to build one high powered Long Wave station that could service their entire country during daylight hours with a national program. In some cases, the smaller MW stations would network to form a second program for the country or, as in the U.K., have these stations offer regional programming for the much of the day. The net result is only one or two stations to tune-in during the day in your language.

This dual band nature of broadcasting and relatively lower requirements for selectivity and sensitivity to bring in stations in your native tongue certainly influenced your buying choices. With a state agency producing broadcast content, there was often the impression that the programs were too 'high class' or 'dry' for the "un-washed masses"; therefore reducing the incentives for many families to invest in a radio. Add to that the nationalism and eventual outbreak of war where it became unpatriotic then even illegal to tune in foreign broadcasts in many countries further influenced the design of radios in the marketplace.

These radios that I will write about came into my collection helter-skelter and the collection is by no means comprehensive so establishing tidy categorical topics has eluded me. Therefore you certainly may find the themes inconsistent. But, let us begin with two small radios….

A little radio of the 1920s
Brand name: Belcanto by Radio-Amato, Germany circa 1927. (Fig. 1)
Extremely compact three tube circuit with single tuned circuit. Fixed regeneration detector followed by two stages of R-C coupled audio amplification to drive a loudspeaker.

On close inspection it appears that Radio-Amato was trying to duplicate the performance of the famous *LOEWE* Type 3NF integrated circuit vacuum tube detector/amplifier used in their OE-333 receiver of 1926. (Fig. 2)

Loewe had been able to get the maximum possible gain from conventional triode element assemblies by the use of very high impedance R-C coupling.

Fig.1. *Belcanto* by Radio-Amato – Tubes so close together they almost touch. There is a reason.

When such high values of resistance are used, wiring stray capacity and inductance become significant limiting factors to usable gain. Their unique solution was to place their hermetically sealed resistors and capacitors within the vacuum envelope of the tube thus greatly reducing these strays to get unmatched performance.

On close study of the *Belcanto* construction, you can see that this was definitely an exercise to come as close as possible to such performance using conventional triodes, capacitors and sealed high value resistors. Apparently this construction made for a reasonably good local receiver. (Fig. 3)

Here in the USA such a fixed regeneration radio would have been quite useless in many major markets simply because single tuned circuit radios without adjustable regeneration have

Fig.2. Advertisement for late version (1929) of their OE-333 receiver using the famous Type 3NF integrated circuit vacuum tube.

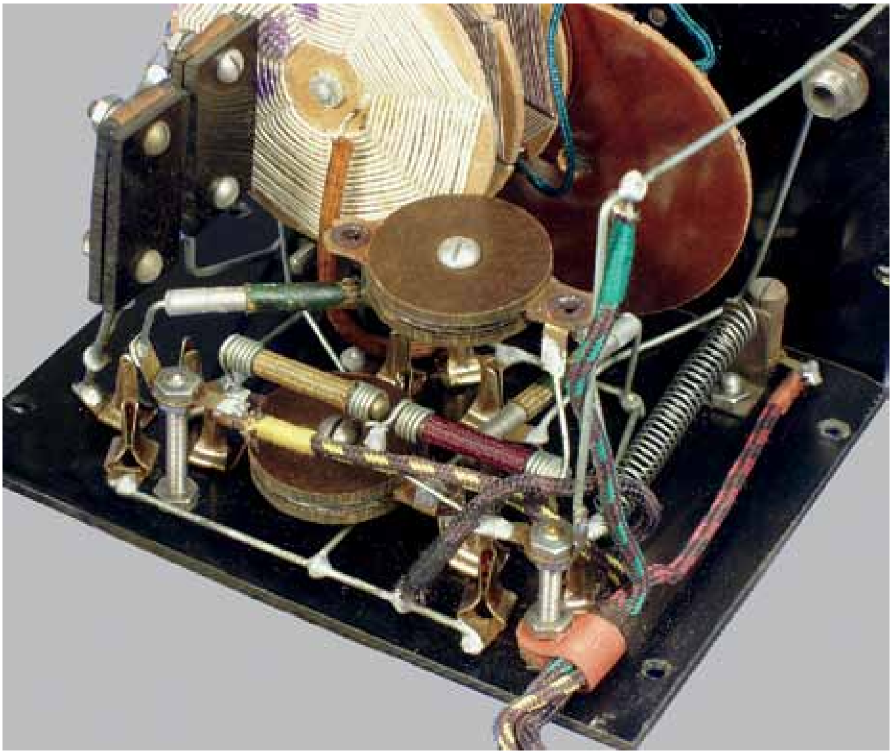

Fig.3. Shortest possible circuit paths to help emulate the Loewe 3NF tube performance using conventional components.

very poor selectivity to separate the many stations on the American airwaves. This was not a problem in most all European countries where broadcasting services were operated by a state controlled agency. In such schemes of the 1920s there was usually only one national program and perhaps a second program for a very large city.

A little radio of the 1950s
Pulgarcito – Super II *by Cradial Radio – (Barcelona) Spain 1957 – (Fig. 4)*

At the time, this was claimed to be the world's smallest, *superheterodyne*, AC mains powered broadcast radio.

At first glance this radio looks exactly like the circa 1952 radio made

Fig.4. Tiny cabinet has no room for a tube filament voltage dropping resistor. This resistor is built into the oversize mains plug.

by E.R.A. – Milan with the brand name *Gnomo*. That radio is a two tube reflex radio claimed to be the world's smallest AC mains powered broadcast radio.

However the *Pulgarcito* cabinet is scaled approximately 17% greater in volume. Just about the size of a man's fist. Within that volume is contained a 3 tube reflexed, inductively tuned superheterodyne receiver with selenium mains rectifier. The ballast resistor required for the filament circuit is built into the over sized mains plug. There are even two tiny lamps to illuminate the tuning dial and backlight the *Pulgarcito* logo. Not only does the little radio tune 575 to 1800 KHz Medium Wave, but also 5.3 to 14.5 MHz. Short Wave!

The density of point-to-point wiring is incredible and must have taken an excessive amount of labor to accomplish. (Fig. 5)

I could find virtually no information on the company to shed light on their operations. Cradial was in business from 1950 to 1958.

A Sr. Lisardo designed the inductive tuning. This scheme was carried over to a new hand wired transistor radio chassis built by a successor company operating with the *Vanguard* brand name. However it was now packaged as the familiar rectangular coat pocket sized portable. This brand continued on until 1985 making radios & TVs.

Fig.5. Movable ferrite core oscillator inductance is on bottom side of the chassis. Dial string links to corresponding ferrite core of antenna inductance located on top of the chassis.

The radio uses Philips branded *Rimlock* tubes (UCH42, UAF42 & UL41). These are miniature tubes with 8 evenly spaced pins on a glass button base. A glass bump on the side of the base is used to index and lock into a die stamped metal ring mounted coaxial to the tube socket on the chassis. The layout of this little radio could not afford the 'luxury' of such indexing rings; therefore making it possible to insert the tube 8 possible ways! Of course 7 are wrong and a few orientations could even damage circuitry. The tubes could not work their way out of the sockets, however; because there was less than 1.5mm clearance between the evacuation tit on the top of the tubes and the inside-top surface of the cabinet! (Fig. 6 – Back cover removed.)

Each tube carries a tax stamp and there appears to be no heat damage on any part of this radio leading me to think it may never have been used.

My late friend Ernie Hite spotted this radio at about 5 AM in the outdoor section at Renningers Antique Market in Adamstown, PA. He held his hand on the little radio, called me on his FRS radio and I made my way to his side to make the purchase. It was a good day....

Fig.6. Tubes stay in place simply because there is only about 1.5 mm clearance to the top of the cabinet. (Back safety cover removed.)

A visit to the UK for three radios, two for now and one in the final segment of this paper

British Thomson-Houston Co. Ltd. Crystal Set – Model Type C. circa 1923

With S. G. Brown Co. Ltd. Microphone Amplifier and Brown loudspeaker. (Fig. 7)

This large 'letter box' format crystal set is not too different from some American crystal sets except for the fact that European sets in general needed to tune not only the Medium Wave band but the Long Wave band from 1000 to 2500 meters. This was often accomplished by plugging in an auxiliary loading coil. The inclusion of two galena detectors in this particular set is rather uncommon.

What really sets this outfit apart is that it is shown driving an S. G. Brown Microphone Amplifier. (Batteries are reproductions.) This is a device that could provide true power gain (amplification) at audio frequencies without the use of a vacuum tube. This was accomplished using a double button carbon microphone element with its center, movable plate mechanically driven by a very sensitive magnetic driver

Fig.7. B.T-H Crystal Set with S.G. Brown Microphone Amplifier & Horn speaker. Powered by 6 Volt dry cell battery.

connected to the output of the crystal set in place of the usual high impedance headphones. (Fig. 8) The center movable plate is in series with a 6 Volt dry cell battery connected to a center tap of a matching transformer. The end taps of the winding are connected to the button contacts on either side of the microphone element. This makes a push-pull winding. The secondary of the transformer is connected to the horn speaker… The usual horn speakers driven from vacuum tube amplifiers had input impedances of around 2,000 Ohms. For most efficient power transfer from the Microphone Amplifier, Brown offered a horn speaker with about 120 Ohm input impedance.

Before the broadcast era Brown had acquired some expertise in manufacturing these microphonic amplifiers from their original application

Fig.8. Even with its precision manufacturing tolerances, frequent adjustment was required for optimum output.

in amplifying long distance telephone circuits. They required precision manufacture and constant adjustment. They were quickly replaced when vacuum tubes became reliable.

I have had my outfit in operation but I must say that I have rarely been able to observe more than about 6 db gain. It does provide a comfortable listening volume in a small, quiet room.

There is even one version where two of these amplifiers are connected in series! Virtually no other manufacturer made such amplifiers in quantity and tried to market these devices to the public.

L. McMichael Co. Ltd. – Slough, Bucks., England – Model "Screened Dimic 3" circa 1928–31. (Fig. 9)

Leslie McMichael had been involved as an amateur wireless experimenter since 1913 and from the WW-I demobilization in 1919, at the age of 34, set up a business to supply the needs of experimenters primarily from the sale of war surplus goods. By late 1922 the business was receiving very favorable reviews of their own manufactured wireless sets.

By 1927 the first versions of R.F.

Fig.9. The cabinet is 'flaky cut' oak and the grain is filled but not leveled; somewhat in the style of the Victorian era Jacobean furniture revival.

screen grid tubes became available to set manufacturers in the U.K.; and the next year, the introduction of the pentode audio amplifier tube made a significant improvement in amplifier power and efficiency.

Messrs. McMichael combined these two innovations with a conventional A. F. triode as a regenerative detector to produce a three tube battery powered radio considered very good in performance on the Medium Wave band and exceptional in performance on Long Waves. Added to that, this receiver employed provisions for interchangeable coils; a box of 3 supplied as standard with the set and 9 other optional coils that would permit coverage from 10,000 to 15 meters. (Figs. 9 & 11)

Correspondence with U.K. collectors indicate no other surviving Dimic 3 sets having such a large assortment of boxed coils.

Coverage of such wavelengths would lead me to think this was purpose built for the radio amateur but the advertising I have seen of the day does not overtly make that distinction. Nor do the detailed reviews given to stand holders at the great Radiolympia Exhibitions by the writers for *Wireless World*.

One interesting side note is that the sets capabilities won the firm contracts to supply these receivers to Crown Agents for the Colonies. I took special note of that statement because included with this radio, was a letter from that well known early US collector and dealer in vintage equipment, Paul Giganti. He stated that he had purchased this radio in 1954 (!) for the outrageous price of $35; his usual limit at the time being $10. So I have wondered if this set might have come from a U.K. consulate office here in the US.

The cabinet is 'flaky cut' oak and the grain is filled but not leveled; somewhat in the style of the Victorian era Jacobean furniture revival; not at all common here but found in a number of early U.K. sets.

The top lid is a single plank with routed edge. Without splined end pieces, such a wide & thin board is prone to splitting. The lid on this radio was missing and I had to create a replica.

The ball bearing vernier drives for the two tuning dials and regeneration control are exceptionally smooth.

You may notice that the grid bias battery has terminations never used in this country. (Fig. 10) Rather than having *Fahnestock* clips or threaded studs with thumb nuts on the battery, the terminations are hollow short brass tubes or formed brass sleeves with an internal diameter of 1/8". This becomes the receptacle for what was commonly referred to as a 'wander plug'. There are many variations of this plug from barely functional to really clever.

This scheme was also employed on 'B' batteries (H.T. batteries) and was a common practice throughout Europe. On the same subject, all these batteries had a paper flap, barrier or sealed pasteboard lid over any of the connections that must be torn off, punctured or removed to gain connection to the battery. It was a sure way for you to know if the battery was new. I don't

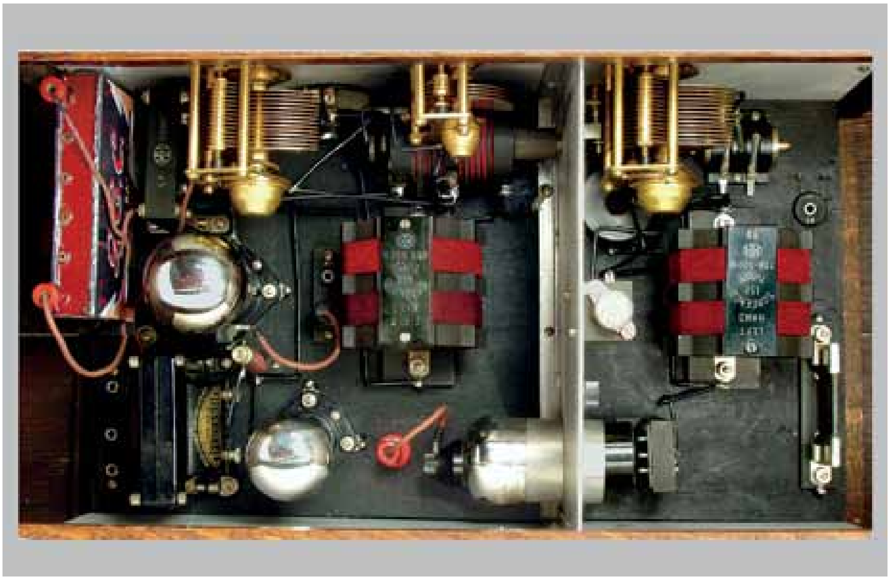

Fig.10. Note grid bias battery terminations and transverse mounting of screen grid R.F. tube.

Fig.11. 3 standard coils were supplied with the receiver. There were 9 other optional coils available.

think any US makers did this here in the 1920s or 30s.

A visit to France for a very nice superheterodyne…

Few French sets are as distinctive as the 1927/28 Radio L.L. Synchrodyne – (Fig. 12)

Using a large dual band (LW/MW) loop antenna and employing a double-grid (bi-grille) type tube for the oscillator/mixer not used here in the USA in the 20s.

Fig.12. A combination loop antenna for Long Wave and Medium Wave reception.

Radio L.L. refers to Lucien Lévy who is, more often than not, credited in Europe as the inventor of the superheterodyne circuit.

This cabinet was designed by the famous furniture designer, Carlo Bugatti while residing in Paris. All the more interesting in that the engine turned aluminum front panel follows the theme of his son, Ettore's, dashboard designs for his highly regarded race cars. Such designs were only a tiny portion of Carlo's design output in furniture. A Web search for: Italradio – Torino, Model Triumphator 6 will show you an even more audacious cabinet design of a few years later.

These cabinet designs make no use of veneering or plywood construction; just solid lumber with the better manufacturers like *Ducretet* and *Radio L. L.* using mahogany.

Chassis construction shows very little use of materials requiring the use of heavy machinery like punch presses with custom dies, or tooling for metal stamping. (Fig. 13) Apparently the volume of production just could not justify such capital outlay.

The chassis layout is very compact. (Fig. 14) The I.F. transformers are tuned by open frame variable capacitors. Each tuning dial is hand calibrated at the factory to read wavelength in meters.

Note the use of inspection lacquer on every screw or nut at connection joints. The two aluminum straps are to retain two 9 Volt grid bias batteries.

A passing note in a *Wireless World* for May 30, 1928 – page 538 states that the "frame aerials are very popular

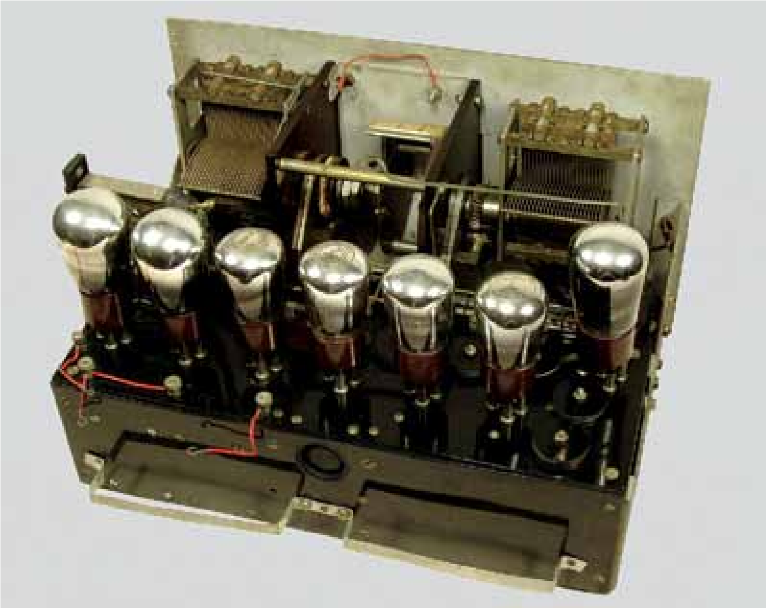

Fig.13. Internal construction shows very little use of materials requiring the use of heavy machinery with custom tooling.

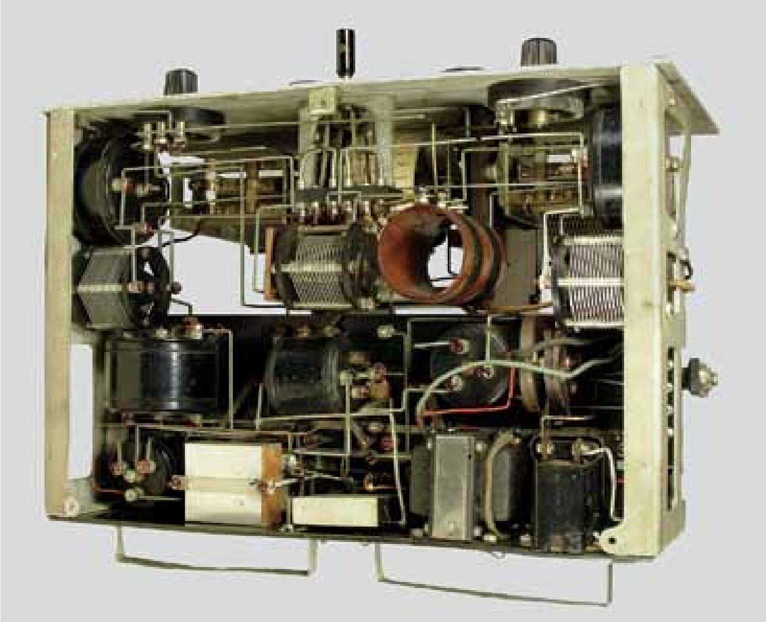

Fig.14. Very compact chassis layout. The I.F. transformers are tuned by open frame variable capacitors.

probably because of the strong objections Paris landlords have to outside aerials".

While the RCA claimed a monopoly on factory built superheterodyne radios during the 1920s here in the USA, Lévy sold a reported 65 licenses for manufacture of superheterodynes in Europe.

Three radios from Italy…

Italian radios of the '20s and '30s are very well made but they are often not so strange to 'American eyes' as regard chassis design. They were heavily influenced by imports from Germany, France and the USA. In the later part of the 1920s one of the major players in that market, *Magneti Marelli*, licensed technology from the likes of *American Bosch* for a radio manufacturing business; and a short time later, was instrumental in setting up Italy's first high capacity vacuum tube manufacturer, *FIVRE*; using *RCA* licensed designs. There are many sets with striking cabinet design; however most of *my* Italian sets are not so visually interesting.

Except maybe for this* CGE *– (Compagnia Generale di Elettricità) – Milan -* Audiola *set of about 1934 with chrome plated face plate behind translucent celluloid sliding doors…. (Figs. 15 & 16)

Modernist case designed by architect, Piero Bottoni; a major influence in Italian Rationalism; part of the international Modernist Movement. The internal development name of this radio was "Baby".

The power transformer is huge!

Figs.15 & 16. Modernist cabinet design – Chrome plated face plate behind translucent celluloid sliding doors.

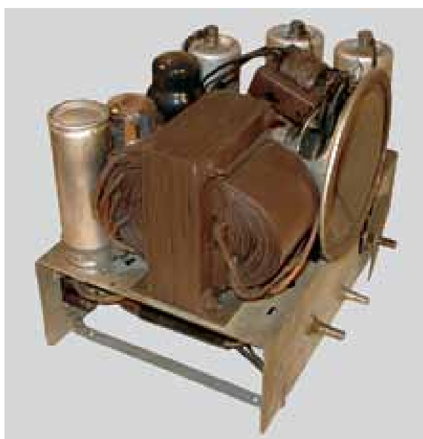

Fig.17. Huge power transformer with 6 input voltage taps (110–230 Volts) and large core to operate at 42–50 Hz.

(Fig. 17) Six primary voltage taps of 110, 130, 150, 170, 190, 200 attest to the fact that power line voltages had not yet been standardized. The transformer frame is so large because the Milan power line frequency was a nominal 42 Hz. This was to cause a problem after WW-II when the national broadcaster, *RAI* was trying to adopt modern TV standards. They could not use this line frequency to sync vertical trace.

Looking at the bottom of the chassis, it is fairly easy to see the 'boat anchor' construction methods of American made *GE* radios of the early 1930s. Dog bone resistors and all…. (Fig. 18)

The 1940 Radio Roma is the least known of the Italian peoples radio.

It is basically a small wood cased cube but the interior contains a 3 tube reflexed superheterodyne of exquisite design and execution. (Fig. 19) This radio was required to be the lowest priced radio in each Italian manufacturer's product offering. The sets are not as highly standardized as the German Peoples radios and there was apparently no enthusiasm for making these sets because they could not be built at a profit. Government subsidies were used to prevent net loss to the manufacturer. The version in my collection was made by *Watt Radio* – Torino.

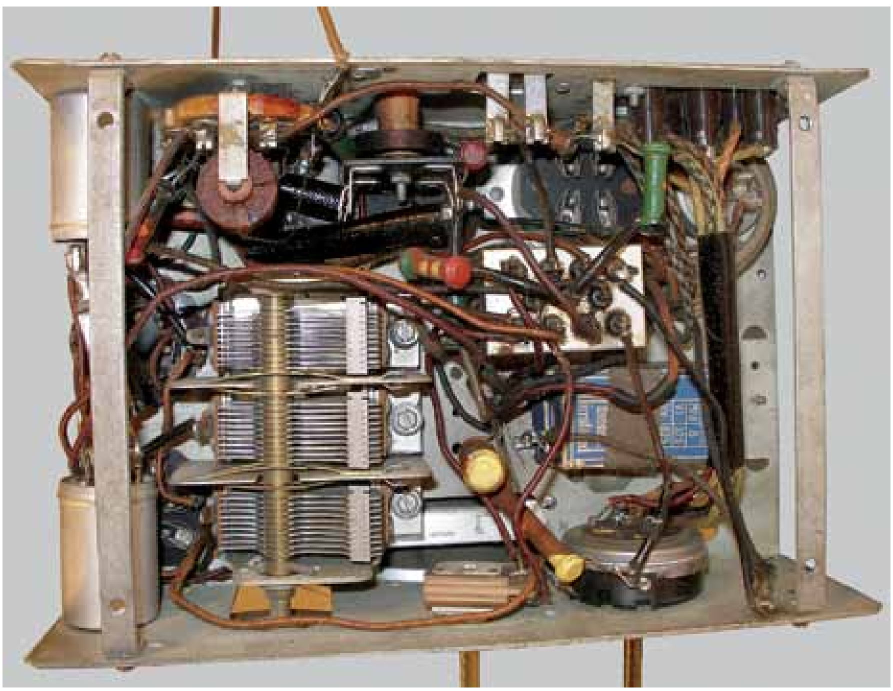

Fig.18. Strong construction similarity to American GE radios of that period. Dog bone resistors and all…

The grill cloth appears unique to me. Rather than a mesh of more or less conventional thread, each strand is actually a strip of crepe paper twisted into a fine cord and then woven into an open mesh. I spent several full afternoons figuring out how to repair the mesh and properly reattach it.

Fig.19. The grill cloth of this Radio Roma is actually woven of twisted crepe paper.

The 3 tube circuit consists of a 6A7, 6AY8 & 80. (Fig. 20) I noted that the 6AY8 seemed to be an American tube design but it is not. It was designed by the largest Italian tube manufacturer *FIVRE* who built very good tubes to RCA patterns. It is electrically equivalent to the side contact EBL1. However this tube was never registered in the US probably because, by 1936, trade sanctions and severed technical cooperation had been imposed on Italian industry because of the invasion of Ethiopia (Abyssinia).

Note that the speaker basket is enveloped by a draw string bag to keep foreign materials out of the voice coil gap; practice common to various manufacturers across the continent. (Fig. 21)

Fig.20. The 6AY8 duodiode – beam power tube in this receiver was never used in the USA. It is equivalent to the side contact EBL1.

Fig.21. Most small components mounted on 'tag boards'. Note cloth bag over speaker to keep voice coil free of contamination.

Components are mounted to two 'tag boards'. Some shielded wiring and careful lead dress were critical to obtaining maximum performance.

'Dial strings' were commonly small diameter music wire rather than fiber materials seen here.

I have this Geloso from the 1954 model year that has typical rounded features emblematic of stylish Italian design from 1940 into the mid 1950s. (Fig. 22)

The founder, John Geloso was born in Argentina January 10th 1901, where his Italian parents had temporarily moved from Italy. The entire family moved back to Savona Italy in 1904, where John studied at the nautical school. After finishing school John started an electromechanical workshop where he manufactured items he had personally patented.

In 1920 he went to the U.S., and began working for Pilot Electric Manufacturing in New York and attending Copper Square University. After graduation, in 1925, he was appointed chief engineer by the Pilot president, Isidor Goldberg.

John was credited with significant innovations in AC power supplies, single dial tuning, acoustic improvements and even was instrumental in demonstrations of scanning disc television circa 1928/29. By 1929 he was heavily involved in the design of the Pilot Super Wasp, the first completely AC operated short-wave receiver in the American market. John had a special interest in trying to eliminate the necessity for plug-in coils.

In 1931 John returned to Milan, Italy to set up his own business producing radio components of high quality and offering kits of components to home constructors. Within just a few years Geloso offered a full range of radios and after the War, televisions, Hi-Fi, tape recorders and very good quality amateur and commercial radio receivers and transmitters. The business continued into the 1970s and at one time had eight factories producing complete

Fig.22. Cabinets with rounded features were emblematic of Italian designs from 1940 to the mid 1950s.

Fig.23. High quality Geloso components such as tuning capacitors, I.F. coils and tube shields were used by other manufacturers.

Fig.24. This particular model contains one of Geloso's extremely compact and efficient RF coil modules.

products and large quantities of parts for other manufacturers. (Fig. 23)

This is where I see a reason to mention features in this Model G-118. Geloso obtained some notoriety for his extremely compact and efficient multi-band RF Coil assemblies and complete tuner assemblies. And this set does indeed have one of the RF modules under the chassis. (Fig. 24)

1961 in the DDR – (East Germany)
The Juwel 2 – Radio/Phono by VEB Stern – Radio Rochlitz (Fig. 25)

When I first saw this set without a 45 RPM record sticking out, I was thinking; what is a tube radio doing with a floppy disk drive?

This high end AM–FM radio is equipped with a record-in-the-slot 45 RPM player. It was designed to operate on 50 Hz power and cannot easily be made to operate on 60 Hz power.

These radios are very complex and require high levels of skill in assembly. (Fig. 26) There are multiple speakers with many options in tonal response curves to insure audio performance not often duplicated in American radios of this vintage.

One feature of this radio is a rotatable ferrite loop antenna. Not unique to European design but certainly not used here in table model sets of this vintage.

There is somewhat of a problem with the elaborate 'piano key' switching matrix seen in this design.

The silver plated contacts are on the

Fig.25. Unusual 45 RPM record-in-the-slot player incorporated into this deluxe table top radio.

Fig.26. This *Juwel 2* chassis is typical highly complex German design yielding performance rarely equaled by contemporary American radios.

Fig.27. The 'Stationized' linear dial so very common in European radios showing a FM band tuning the Eastern Bloc frequency range of 65 to 74 MHz.

top side of the assembly and largely open to the settling of dust and other contaminants that usually collect on the tops of chassis and can certainly promote corrosion in less than ideal environments.

When you look at the dial, (Fig. 27), you may notice while the radio is indeed AM/FM, the FM band (marked UK) is the Eastern Bloc frequency range of 65 to 74 MHz. Here you also see the 'Stationized' dials so common on European radios from the mid 1930s onward. Not really practical here with the much higher density of broadcast stations.

Fig.28. *Elektrit* was the only Polish brand in the 1930s to enjoy a significant export business.

While in the eastern area of Europe, here are two pre-WW-II radios from Poland

The Elektrit* Kordial *Type 2 – Vilnius, Poland – (Fig. 28)

Manufactured by the largest privately owned business in Vilnius, Poland; only five months before the German invasion of 1939. This was a Jewish owned business with largely Jewish engineering and skilled craftsmen. (Elektrit Radiotechnical Society)

The lowest cost *Elektrit* receivers of the mid and late 1930s were 'local' receivers featuring a regenerative detector, pentode audio output and rectifier. The Kordial adds another tube to the circuit, a highly refined TRF amplifier stage. In general the 'build quality' of these radios appear to be quite good by continental European standards and somewhat better than that of the Polish State industry. *Elektrit* was the only significant Polish owned exporter of radios.

Here are some features you will not see on a contemporary USA table radio of this time.

With just four tubes, it was still important to have a 18–50 meter short wave band in addition to the usual 200–580 meter medium wave band and 700–2000 meter long wave band.

This TRF receiver has a form of AVC with apparently limited dynamic range. There are two controls, regeneration (Volume) which is coupled to the power (mains) switch and RF gain (Sensitivity) in the first stage tube (EF9). A proper balance of the settings of the sensitivity and volume controls would give satisfactory operation.

This receiver and apparently many other Polish receivers of this time period feature tunable notch filters in the antenna circuits for long wave & medium wave bands. (Fig. 29) This would make it easier to prevent the local city station from overpowering a high gain RF amplifier or regenerative detector. (More expensive radios using the superheterodyne circuit would not have needed these filters in most home locations.)

The phonograph input is considered unusual in that it applies the magnetic pickup to the screen grid of the detector tube. One writer explains that the full gain of this stage would have overloaded the pentode output tube if the phono signal had been coupled to the grid of the detector.

On the back panel there is a two position tone lever switch and an interesting toggle switch called an 'economizer'. It selects lower taps on the HT transformer winding to increase the life of the tubes and lower overall power dissipation.

Fig.29. The brown faced box on the left side of the chassis contains two tunable antenna notch filters (one for LW & one for MW) to prevent overloading the high gain tuned RF stage of this radio.

The radio has a permanent magnet dynamic loudspeaker. This probably because there was not enough B+ current in the four tube circuit to energize a speaker field coil in the fashion common in American 5 tube radios. It would have also complicated the 'economizer' circuit. This radio operates over a wide range of AC voltages. A common necessity because the electricity grids were not standardized in the early part of the 20th century in many areas throughout Europe.

This set, like products of many other European manufacturers, uses a cloth bag over the entire speaker basket to keep the voice coil magnetic gap clean.

As one of the two major

Polish radio producers and the only one in the area annexed by the Soviet Union after the Germans were defeated, the firm was nationalized and then dissolved. Its property was dismantled and transported to Minsk where the Viacheslav Molotov Radio Factory was set up. A large group of the engineers and skilled workers were arrested and resettled in Minsk as forced laborers. By 1945, an essentially identical radio was being manufactured there.

Let us back up a few years to a set I call a survivor…. This time it is a product of a state owned Polish industry

Fig.30. This *ECHO* model PZT-121-Z is essentially electrically equivalent to the German VE-301 Peoples Radio.

ECHO *Model PZT-121-Z Warsaw – circa 1935. – (Fig. 30)*

This radio circuit is electrically equivalent to the German 'Peoples Radio' VE-301. That State sponsored design was released to German manufacturers in late 1933. Volume is controlled by varying regeneration via a small split stator variable capacitor. What sets this Polish radio apart from the VE-301 is the innovative way they simplified the wave band selection for the user. The German design required that you shift antenna connections on a plug board located on the left side of the radio. In the Echo, a six position slide switch was added to the base of the coil assembly and actuated via a lever in the front panel of the radio. This made the wave change very easy. (Figs. 31 & 32)

On the back of the receiver there is an adjustable wave trap to prevent overload of the receiver from a local station. (I think it interesting to note that there were a couple of German radio manufacturers that developed proprietary attachments for the VE-301. One of them was a plug-in module for the previously mentioned plug board with pushbuttons to make the wave change selection. It also had a tunable wave trap. One manufacturer even went so far as to offer an add-on TRF amplifier for the VE-301.)

Why do I call my PZT-121-Z a survivor? If you will look closely at the mains cord (power cord) you might be able to see that it has a strange plug. (Fig. 33) This type of plug was used in Australia and New Zealand and sure enough, this radio showed up on eBay Australia. The power transformer is not original but was certainly replaced before the end of WW-II. By the late 1940s this radio would have been regarded as completely obsolete and sent to the attic even though it appears to be minimally functional even now. Thanks to

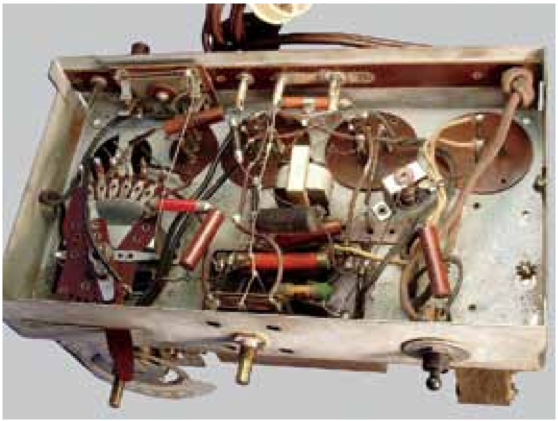

Fig.31. The plug board wavelength selector scheme of the VE-301 was replaced by an elegant 6 position slide switch and modular inductor.

Fig.32. Note the PZT logo on the gold spray shield tube made by Philips in Poland.

Fig.33. A single tunable antenna notch filter is mounted to the back wall of the chassis. Note the mains plug, a design used in Australia since 1937.

my friend, Stephen Brown, it is now in my collection.

History tells us that as the anti-Jewish rhetoric in parts of Europe increased in the late 1930s, a lot of German and Polish Jews left these countries. Australia already had been welcoming Jewish immigrants for close to a century. In 1938, Australia allotted 15,000 visas for "victims of oppression" and some 7,000 Jews took advantage of the program before the outbreak of war. Before things got really bad, these people were able to take some belongings with them, and a compact radio like this *Echo* would certainly have been a prized possession at the time.

Fig.34. Controls mounted on the side of the cabinet concealed by a door. Instruction manual fits under clips mounted to the door.

Three radios from Nordic countries…
From Sweden, an early 1930s* Radiola *312V made by* Svenska Radio *AB - 1931/32 (Fig. 34)

Not at all related to the RCA *Radiolas*…. RCA's agents were literally hours behind agents for L. M. Ericsson (*Svenska Radio AB*) in making a

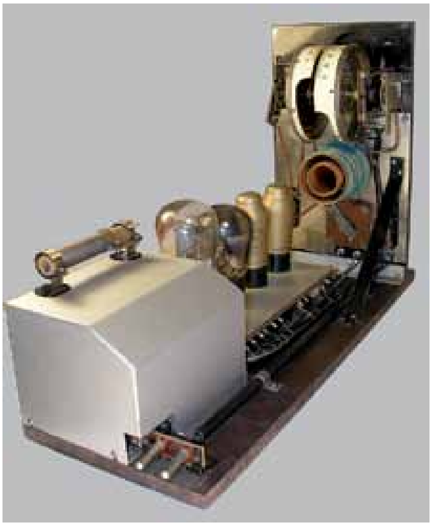

Fig.35. Large power resistor with adjustable tap in series with the primary of the power transformer permits operation from a wide range of voltages.

Fig.36. When paired with this Gramophone table option, this simple radio becomes quite the modernistic design statement.

filing to trademark the *Radiola* brand in Sweden.

Their radios of the 1920s were very simple designs with what seem unconventional control layouts… This one has the controls concealed behind a door on the side. The loudspeaker is of the free edge cone variety with pin driver.

It has just one stage of TRF with regenerative feedback and pentode output. (Fig. 35) Operation from various line voltages is made by a simple half wave rectifier supplied thru a mains side high wattage dropper resistor that clips into terminals on the top of the power transformer. The radio tunes from 190 to 2150 M in four bands.

There is provision for a magnetic Gramophone input.

There was an interesting Gramophone turntable optional base available. In the base was a small record storage box. This option turned this rather plain cabinet into a uniquely modernist art statement. (Fig. 36)

However, within two years Swedish radio design would appear somewhat similar to cabinet design themes of the Germans while the chassis design is very similar to American practice although with somewhat greater attention to assembly detail and quality of passive components.

The 1939 RADIONETTE* "AlleLand"—superen *from Norway. (Fig. 37)

In addition to tax stamps on the vacuum tubes as seen on the Spanish *Pulgarcito*; there is a Manila paper tag on the line cord containing several tax stamps specific to the purchase of the radio. (Fig. 38) The tubes are Sylvania brand. This company was also a major

Fig.37. The cabinet is of 'flame birch' a common Nordic wood species.

Fig.38 Note paper tag covered with tax stamps to cover purchase of the radio. Tubes were taxed separately.

Fig.39. Removable & repairable spring loaded mains switch held closed by low temperature solder. Fits in pocket between transformer windings.

tube supplier for the Swedish company *Luxor Radio AB*.

On looking at the chassis from the top side, there is not much unusual, however on the bottom side I found a feature not seen on any American made radio that I know about. (Fig. 39)

Inserted between windings of the power transformer there is a spring loaded thermal circuit breaker. The circuit is kept closed by low temperature solder between two copper alloy strips. When the solder melts, the strips can slip past each other and open the mains circuit. If the transformer over heat condition was caused by a short elsewhere in the radio, the circuit breaker could be pulled out of its pocket between windings, re-soldered to close the circuit and inserted back in place.

Fig.40. With four knobs on the front, one might expect a 5 or 6 tube circuit. – Not so in the MINI – 508K.

And now for a little Danish Modern… Circa 1953

The Bang & Olufsen - MINI-508 K (Fig. 40)

With four knobs on the front, one might expect a 5 or 6 tube circuit. – Not so in the MINI.

It is another three tube superhet with selenium rectifier (2 x UCH21 & UBL11) from a relatively small

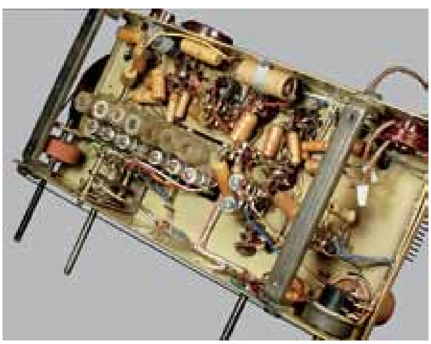

Fig.41. Unequaled skill in assembly with laced wiring harness. All connections and adjustments coated with red & green inspection lacquer.

Fig.42. The I.F. transformers have octal tube socket bases that plug into the chassis. How was this cost effective?

company with legendary reputation for highest quality in design and manufacture that still endures today as perhaps the # 1 luxury brand for audiophile loudspeaker systems.

Unequaled skill in assembly with laced wiring harness. Transparent red & green Inspection lacquer on all solder joints, something only seen here inside of military grade electronics. (Fig. 41)

But what were they thinking? (Fig. 42) The I.F. cans are mounted on octal sockets! This did make it possible to align the I.F. transformers on a separate test fixture which may have been marginally faster to do in a specialized receiver but it does seem like it would have been difficult to offset the expense of the octal plug and socket.

German sets of the Weimar Republic era (1919 to 1933) are generally considered ugly to American eyes but contain very interesting internal design features.

Rather than say ugly, maybe I could call it a Spartan theme, is certainly carried into this *NORA* model K3Wf of 1930; an example of the countries very first series of AC powered radios with built-in loudspeakers. (Fig. 43)

Note that the control panel tilts out but this cannot be done until the power cord is unplugged. (Safety interlock that was a requirement of national standards.) (Fig. 44)

Most of these early sets were still using pin-driver loudspeakers. This made it easier to design small power supplies that could be operated on wide mains voltage ranges.

By this time the cold cathode rectifier such as the *Raytheon* BH was 'dead' in American design but still being used

Fig.43. This NORA K3Wf represents the first series of German table radios to have a built-in speaker and are mains powered.

Fig.44. Electrical standards of the day required that the mains be disconnected if the cabinet were open.

Fig.45. German manufacturers were the first to develop high stability high value resistors that remain within tolerance even after 80+ years.

in this radio. (RGN 1500) But it is interesting to note that the radio also has provisions for the use of a hot cathode rectifier such as the RGN 504.

NORA and other late 20s German manufacturers had adopted the use of hermetically sealed high value carbon film resistors. (Fig. 45) It is interesting to note that these parts still exhibit correct value even after 80+ years. But they must have been relatively expensive to make and never gained traction here in the USA consumer market.

All of the tuning capacitors use phenol resin impregnated paper insulation between the capacitor plates so that a much more compact variable capacitor could be made. These parts, however, could not be used in ganged arrangements or in highly selective circuits. These insulating sheets would move slightly during rotation of the stator vanes causing slight and variable nonlinearity in the capacity change per degree. But that was sort-of OK at this time because of the limited number of broadcast stations within range; single tuned circuits were still common.

This particular set was exported to and sold for use in Italy. For this reason the power transformer has 4 taps ranging from 110 to 150 Volts rather than having taps for 120, 220 & 240 Volts. At this time, probably 70% of AC powered sets sold in Italy were built in Germany or France. You will even find Atwater Kent and Crosley sets being sold nation wide. A few major Italian manufacturers would increase their production rapidly in the 1928 to 1934 period to capture about 50% of the market. Philips, Telefunken, Siemens, General Electric of Italy (CGE) and other foreign manufacturers would establish plants in Italy during the early 30s. This was done in order to remain in the marketplace after the government established protectionist regulations and even more so after the League of Nations began trade sanctions against the Fascist regime.

Not many American vintage radio enthusiasts know that Hungary had a Peoples Radio (Néprádió) before WW-II similar to the German DKE-38. (Figs. 46 & 47)

Not so surprising when you learn that under the leader, Miklós Horthy, regent of the Kingdom of Hungary; eventually entered into alliances with Nazi Germany after the *Munich Agreement*

Figs. 46 & 47. At left is the pre-war set similar to the DKE-38. On the right is the Communist era 'channelized' receiver.

(1938) allowed Hungary to regain some of its lands lost after WW-I.

This radio was made by four of Hungary's manufacturers, *Orion*, *Philips*, *Telefunken* and *Standard*. My set was made by *Orion*. These sets have a more ornate façade with a theme of Kingdom of Hungary heraldry.

The interior uses the same idea of phenolic resin impregnated paper board sheet stock for the chassis and a molded version of the same material for the loudspeaker basket. The same tubes are used but the radio only tunes the Medium Wave band. Operation over a wide range of mains voltages, 105, 125, 150 & 220 Volts, is accomplished by use of a small auto-transformer unlike the German design that uses a dropper resistor for not as large a voltage range.

My radio is in poor condition having major cracks that were repaired in not the best way. The collector also placed high priority in having his radios "work" often regardless of maintaining historical accuracy. While now quite scarce even in Europe, it is worthy of preservation as long as the historical inaccuracies are documented.

The Peoples Radio concept continued into the Communist era in Hungary beginning in 1950 with a new design built by *Orion*, *Philips* (*RAVA*), *Telefunken* & *Siemens*. The pre-war radio was primarily for local reception. This post-war set was a superheterodyne insuring adequate reception in all parts of the country.

This time though, the basic design had eliminated the tuning dial and used a two position switch to tune in the

two national radio program channels named Kossuth Rádió and Petőfi Rádió.

One could suspect that the Peoples Republic of Hungary did not really want their masses easily tuning into Western stations not so far away. Sad to say that even in 2014 North Korea still permits only channelized radios and televisions with severe penalties for tuning-in outside broadcasts.

And then there is.... PHILIPS

It would just about be impossible to escape having found *Philips* brand radios that are definitely strange to American eyes. After all, by 1933, *Philips* claimed to be the largest radio manufacturer in the world. In the depths of the Great Depression the company moved much of its growing manufacturing from the Netherlands to other countries as governments moved to protect domestic industry. While much engineering expertise was centered in the Netherlands, there was significant engineering staff elsewhere that sometimes produced interesting variations. So as a finale to this tour of distinctively European radio design I offer this trio of *Philips* radios that have made their way into my collection.

Somewhat of a mystery* Philips *radio from France – circa 1942. It appears to be identical to the* Philips *A52A /* Radiola *RA142A but the builders tag

identifies it as a 33W. (Fig. 48)
The first feature to grab my attention is that the chassis is a single, very robust Bakelite molding incorporating all component mounting holes and Philips type side contact tube sockets. (Fig. 49) This approach was tried by Zenith Radio Corp. here in the USA for their 1940 series of radios using chassis as in the model 6D410 and 22 other models in their huge product offering for that year.

Unfortunately the *Zenith* chassis was very compact, far too delicate and ran too hot. There was so much breakage during assembly and distribution that the entire production of this chassis was abandoned after approximately five months. *Zenith* returned

Fig.48. French made version of the A52A / Radiola RA-142A but apparently made for export to German speaking areas.

Fig.49. The chassis is a single robust Bakelite molding complete with tube sockets. The Speaker basket is also molded in Bakelite.

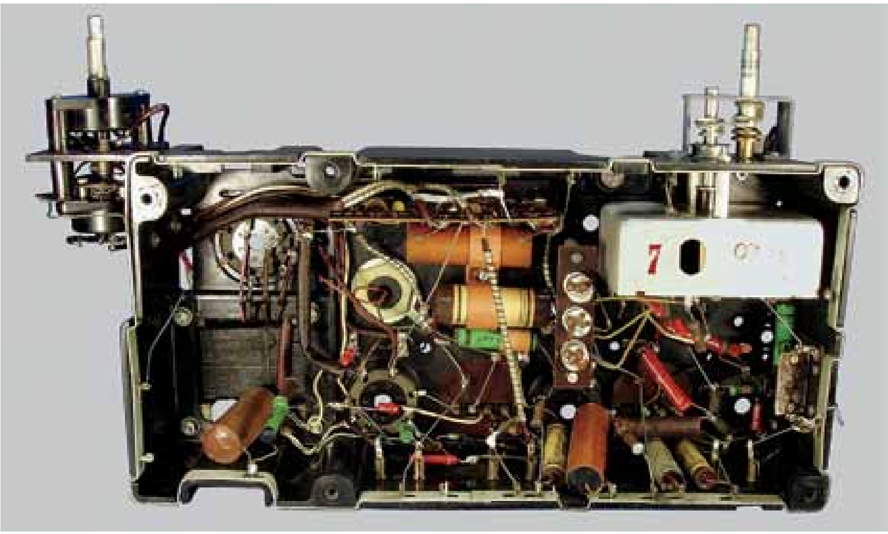

Fig.50. Two metal strips with 40 bends form the ground buss for the radio. There is some shielded wiring that would not have been required in a conventional metal chassis.

to conventional sheet metal chassis. An interesting side note is that Harold Cones in doing research on *Zenith* found no corporate records, controlled by Eugene McDonald, regarding this project. Apparently he did not want to be reminded of failure of a very expensive tooling and production line set-up project.

Every practical receiver design requires some kind of a ground buss. This was accomplished in the A52 by two metal straps with 22 and 18 bends respectively inserted into slots molded along the bottom edge of the chassis. (Fig. 50) There are a number of shielded wires that probably would not have been required had the chassis been the more conventional sheet metal variety. As with many *Philips* radios, the assembly is of the highest standards.

This radio contains another example of a resettable thermal circuit breaker. This time the approach is to embed a copper bar between windings of the power transformer. A hook formed on one end of the bar sticks out from between windings and a small D shaped link placed on the hook holds a line voltage switch closed. If enough heat is conducted to the D link, the low temperature solder that holds the link together gives way to fall off and open the line voltage circuit. The loudspeaker basket is also a molded Bakelite part.

Back to the builder tag….

Radiomuseum.org indicates that *Philips – Deutschland* manufactured the A60 (The A52 chassis with the addition of a tuning eye.) in 1941 or 42 but does not list the A52. The capacitors in my 33W are all branded CE and are marked in French so I conclude that it was indeed built in occupied France.

The dial glass is typical of many European radios in that the dial is 'stationized'. i.e. In addition to frequency markings, the dial locations of prominent broadcast stations are shown. However none of the usual Allied Nations stations are shown and the wave band markings use German abbreviations (KW,MW & LW), not French (OC,PO & GO) It is my speculation that the 33W tag marking was for radios exported to Germany; the German industry being engaged in war production.

Mullard *MAS-24 – 1937/38 – Equivalent to the Philips 660A*

I am delighted to have a *Mullard* MAS-24 in my collection and understand that this is essentially a Dutch *Philips* 660A design in a different cabinet.

Initially the way *Philips* had developed a presence in the U.K. market was when the *Mullard Radio Valve*

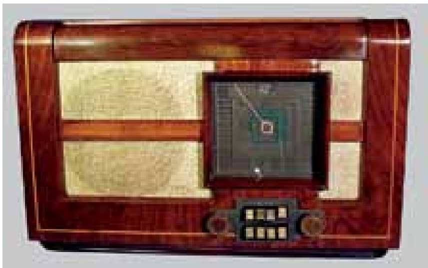

Fig.51. On both sides of the Atlantic, 1937 was the year for mass adoption of pushbutton tuning. But this radio has a truly novel approach to the task.

Company entered into a partnership (in 1923) with *Philips* to gain vacuum tube manufacturing expertise. In 1927, Philips purchased all the shares of the company but continued to use the *Mullard* brand name as it expanded into the domestic manufacture of radios.

Fig.52. Three sets of high precision brass spirals mesh to tune the receiver.

1937 was 'the year' when many major manufacturers throughout the world first introduced variations on pushbutton selection tuning for favorite stations. And Philips certainly had a novel way to approach the task. (Fig. 51)

They called it 'direct tune'. Its unique construction employs three sets of two incredibly precise brass foil spirals of about 8 turns that mesh with clearances that seem to be less than 0.010". Three of the spirals move in and out on a common shaft. (Fig.52)

The RF coils also appear unique in the way they were tuned. (Fig. 53)

At the end of their assembly, they

Fig.53. The R.F. coils were tuned on a semi-automatic fixture that rolled grooves into the aluminum can to the proper size. After this operation, it is impossible to remove the coils for repair.

were placed on a semi-automatic machine that rolled grooves of the necessary depth into the aluminum can at three points prior to installation on the chassis. After this tuning operation, it is impossible to remove the coil to make repairs.

The cabinet employs extremely dense 9 ply - hardwood plywood; used to insure that the cabinet would not resonate (boom).

There is a feedback winding on the audio output transformer for control of volume thru positive or negative phase coupling of the high gain pentode output tube…. This feedback also factors in the mechanical loading of the speaker cone giving more precise control of audio response.

The last radio of note in this trio was built in Germany; the* Philips *D57AU of 1937/38 – (Fig. 54)

Their famous *Monoknob* design with an accessory feature I have never seen elsewhere.

In my opinion the sound quality of this particular receiver is unmatched by any American table model radio of the day.

The unique *Monoknob* design employs a joystick connected to two *Bowden* cables (push-pull) that, with an up/down movement of the joystick controls the volume. Movement right/left controls tone. Twisting the knob about 60 degrees right or left engages quick tuning up and down the dial with fine tuning in between those limits.

Three more *Bowden* cables connect to the dial scale that can be tilted to lie flush with or up to, but not quite, perpendicular to the cabinet top for easy reading.

Two levers either side of the joystick are for variable selectivity and wave band / gramophone selection.

As with the *Mullard* MAS-25, this radio uses RF transformers that were tuned on a semi-automatic machine before mounting in the radio. (Fig. 55)

But unlike the *Mullard* MAS-24, this radio uses a more or less conventional tuning condenser.

Fig.54. The famous *Monoknob* joy-stick controlled series. Dial scale tilts to your preference.

Fig.55. RF coils like the MAS-24 but Philips uses the more familiar type of tuning capacitor. Note the cylindrical module suspended from the top of the cabinet.

The really unusual feature of this radio is the optional DC mains to AC converter. (Fig. 56) This large assembly hangs suspended under the top of the cabinet on a sheet metal bracket. Half of the assembly is a DC mains input module designed to run from either 110 to 145 VDC or 200 to 245 VDC. The selected voltage range module plugs into a mechanical vibrator circuit to provide an output of 220 VAC to operate the radio in the usual way. It appears to have been available on only three Philips models… D56, D57 & D58.

There is an interesting and famous video that you can find on the Web advertising a French version of the *Monoknob*. The title is: *La Grande Revue Philips – 1938*. There are a number of encodings available so you may want to try more than one to get the best image. (Fig. 57)

Fig.56. Optional DC Mains converter. You choose one of two DC mains input modules that plug into a vibrator circuit that outputs 220 VAC to power the radio in the usual way.

Fig.57. This 5 minute *Puppetoon* movie advertises this series of *Monoknob* Philips receivers. You can find it on YouTube and other sites in varying quality.

Philips by WW-II had manufacturing or assembly operations in many European countries and as far away as Argentina, Australia & New Zealand.

This five minute color animation film is certainly international in its scope having been made in Hollywood, produced by the Hungarian immigrant, George Pal, shown in French theaters, featuring American pop music of the day, depicting racial, social and ethnic American stereotypes, played by the famous British dance band of Bert Ambrose!

Closing

So there you have it, a diverse collection of radios that just happened to come my way; acquired primarily because of the novelty of their construction when viewed by this American native. In large part, thanks to the chance opportunity of meeting a gregarious Italian that I was soon able to call a good friend.

Perhaps this paper will spark your interest in learning more of the socio-economic environments in which these artifacts were created for a better understanding of why they might be 'Strange to *Your* American Eyes'.

Acknowledgements

My thanks to the late Italian national, Vic Franzoni for sparking my early interest in home broadcast receivers

made outside of the USA. In 1989, he and his wife Margaret invited me to his home in northern Italy for a terrific 10 day tour of private radio collections. His introductions provided further avenues for gathering information for more than a decade.

For fueling my enthusiasm; the publications of MOSÉ EDIZIONI – Most notably, ANTIQUE RADIO magazine. www.antiqueradio.it

To my long-time 'Swedish brothers' Anders Widell and Bengt Svensson; well known and respected visitors to the AWA annual conferences.

And to my friends, Stephen Brown and Ron Lawrence for notifying me of interesting international items up for auction.

About the Author

For over 45 years **Robert E. Lozier, Jr** has been a collector of radio broadcast receivers and related items. He enjoys preparing radio equipment for exhibition while also documenting the hardware and methods employed for conservation and restoration.

He has prepared lectures and demonstrations on numerous occasions on subjects as diverse as the history of the Magnavox Company, radio collecting in Italy, ultrasonic cleaning & electroplating techniques, and demonstrations of electromechanical scanning television and its history. His paper, RICEVITORE POPOLARE ITALIANO (The Italian People's Receiver) appeared in Volume 7 of THE AWA REVIEW.

In recent years he has become aware of the near complete loss of battery artifacts from before 1935. Items absolutely necessary for the operation of a large percentage of receivers that are so prized in various collections today. He now spends a significant portion of his spare time in creating museum grade replicas.

He retired in 2012 having worked in the engineering department of a Siemens manufacturing facility in Charlotte, NC for 25 years up until the facility closed in 1999. The final 13 years till retirement was spent at a small contract engineering firm as Compliance Test Engineer and Electromechanical Engineer.

Robert E. Lozier, Jr.

Hugo Gernsback: Predicting Radio Broadcasting, 1919–1924

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Abstract

Hugo Gernsback was a critical thinker. He understood the history of wireless communication beginning with Marconi, he knew about the early experiments with voice transmission by de Forest and others. He comprehended the needs of a growing audience of radio parts consumers and he marketed and sold them through his mail order company, Electro-Importing. Following WWI he began to synthesize several decades of technical content for a magazine he called *Radio Amateur News*, changed to *Radio News* a year later. His was the major voice predicting the transition from radio as code for young men with crystal sets and headphones, to a family medium that would actually broadcast entertainment into the home in a manner that all in the family could enjoy. His connection with inventors, programmers and manufacturers allowed him to know and publish monthly stories on the latest trends in radio. He was a strong voice against the possibility of government control of radio, he profited through advertising for the latest radio receiver and loudspeaker, and he became a trusted voice that united both creator and audience in that important period of time known as the "Radio Boom," 1919–1923.

Hugo Gernsback: The Power of the Pen

Did early 20th Century publisher Hugo Gernsback predict or merely report the coming of radio broadcasting in the early 1920s? The evidence suggests that he was both an active student of wireless and radio history and a critical thinker concerning radio's future as a public entertainment medium. Gernsback early on had one foot in a past of ham operators with crystal sets and headphones, and the other in a hazy future of music and news programming for a citizen audience. Through his numerous electricity and radio-themed publications Gernsback often editorialized as a conservative scold, exhorting his readers to fight government control of radio, while at other times he served as a cheerleader who saw a radio boom with entertainment programs and sponsor support. And he wrote about and advertised the equipment for the reception of the evolving programming formats. In the modern context he was full service, both hardware and software.

So were his opinions original, the result of research and conclusions? Did he influence the creation of broadcasting by radio or did he just write about it after it had already taken place? Surely Gernsback was in the right place at the right time: The years between 1919 and 1923 were those in which America moved from war to peace, and from the use of radio by hams and commercial operators to an active audience seeking to dance, be informed, and consume. The explosion that was radio broadcasting could only have happened in a post-WWI social and economic environment. Hugo Gernsback primarily through *Radio News* helped make it happen.

As one who published articles for hams and radio hobbyists beginning with *Modern Electrics* in 1908, and who used his name to sell the parts for wireless construction, Gernsback had to have known about and understood the importance of Edison and Marconi, and the significance of the early radiotelephone experiments of Fessenden, de Forest and others. This influence must have inspired his role as an opinion-leader in the new uses of radio through his mail order catalogues, magazines and the products that propelled his business.

Fig.1. Hugo Gernsback

Moreover, the evidence suggests that 1920 was radio's most important year. Prior to 1920, the words radio broadcasting were used less often than radiotelephone concerts or wireless concerts. and these were erratic events, far from the current 24 hour broadcast day. There were even a few learned definitions of what was an amateur experiment and what was radio broadcasting for the public. The influential George Clark, RCA historian, offered this definition. To be considered a "broadcast" it had to adhere to this criteria: it had to be regularly scheduled, it had to be pre-announced in the press, it had to be entertainment or information, and it had to be listened to by a citizen audience.[1] It was this last tenet that ruled out as "broadcasters" anyone who was on the air before 1920, as he believed correctly that prior to KDKA the audiences were almost entirely young boys who had to build their own radios. That was hardly a "citizen audience." A few years later Gernsback offered, post radio boom, this definition in his 1922 book: "By modern broadcasting is understood a radio intelligence that is sent out at a certain pre-determined schedule or program."[2]

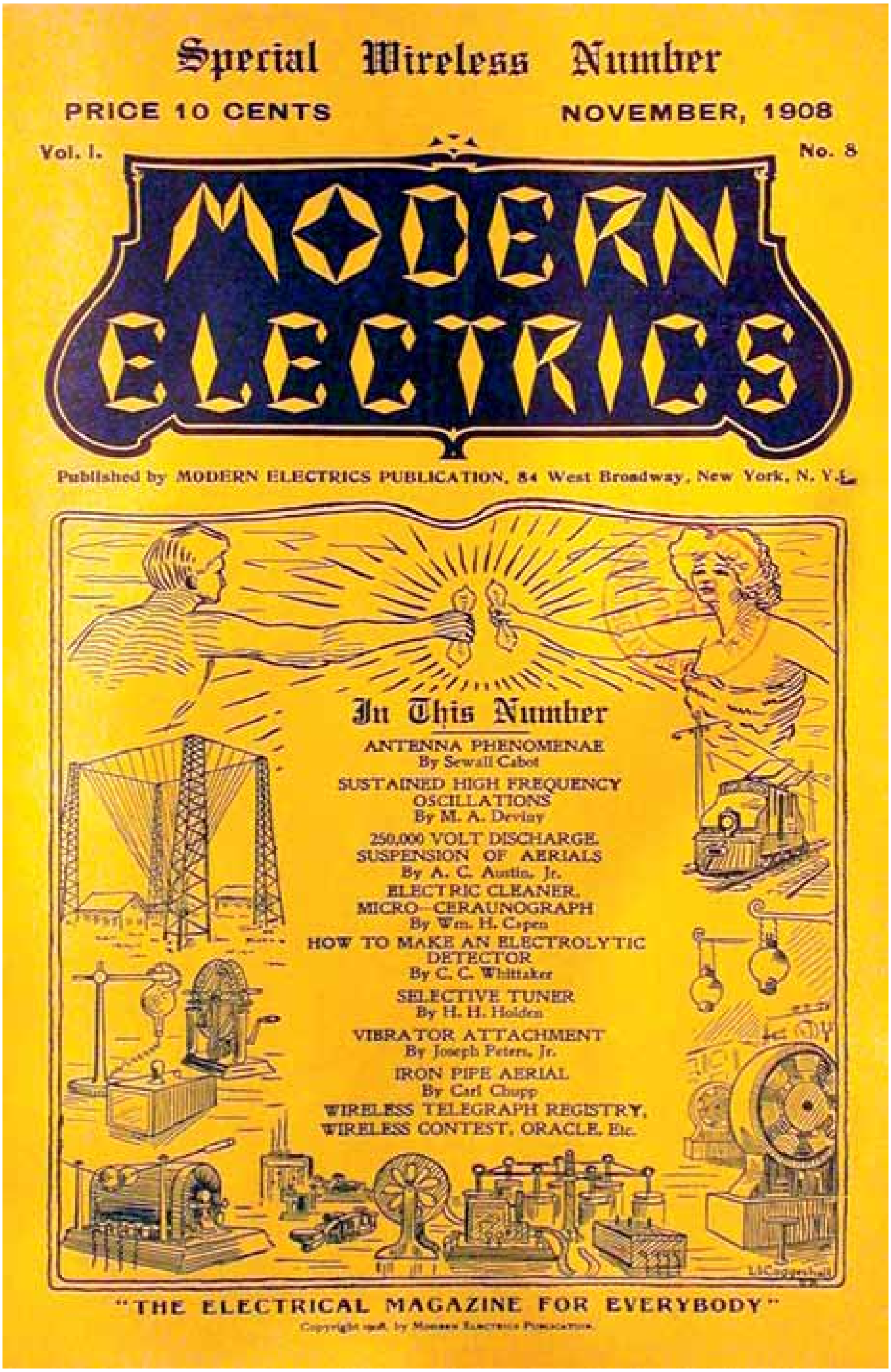


Fig.2. Pre-Radio News cover (credit: Franz Pichler).

Fig.3. Pre-Radio News cover (credit: Franz Pichler).

So while Hugo Gernsback is not a name immediately associated with the development of radio broadcasting, this prolific publisher predicted, promoted, and profited from what radio was to become in the years immediately following WWI. Beginning as the earliest publisher of amateur radio magazines, he both supported and wrote about the transition from all-wireless communication to radio as the most important media of the Twentieth Century. His major pre-war magazines were *Modern Electrics*, *Electrician and Mechanic*, and *Electrical Experimenter*. In the early years of the 20th Century Gernsback was the champion of the young boy radio hobbyist and set builder. He led the way by putting into print the triumphs of Edison, Marconi, de Forest and others engaged in the science of electricity.

Fig.4. Pre-Radio News cover (credit: Franz Pichler).

Not-So-Humble Beginnings

Born in Luxembourg in 1884 as Hugo Gernsbacher, he emigrated to the United States at age 19 and shortened his name to Gernsback. He was a curious person, fascinated by the science fiction and fantasy of H.G. Wells and Jules Verne. And while he was raised in Luxembourg, his parents were from the Baden and Karlsruhe areas of Southern Germany, significant because some of the early experiments by Heinrich Hertz took place in that area between 1886 and 1888. At least it can be speculated that the scientific legacy of his families' homeland may have had some small influence on the elder Gernsbachers as they raised their son Hugo. Perhaps knowing about Hertz, they may have encouraged his interest in electricity.

According to a new book by fellow *AWA Review* writer Franz Pichler, titled *Hugo Gernsback und Seine technischen Magazine*, Trauner Verlag, 2013, "Early on, Hugo Gernsback was interested in electricity," and having received a battery from his parents as an eighth birthday present, and seeing how it

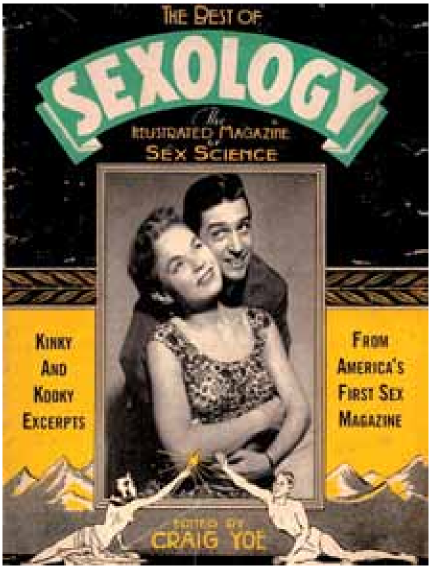
Fig.5. Young Gernsback (credit: Franz Pichler)

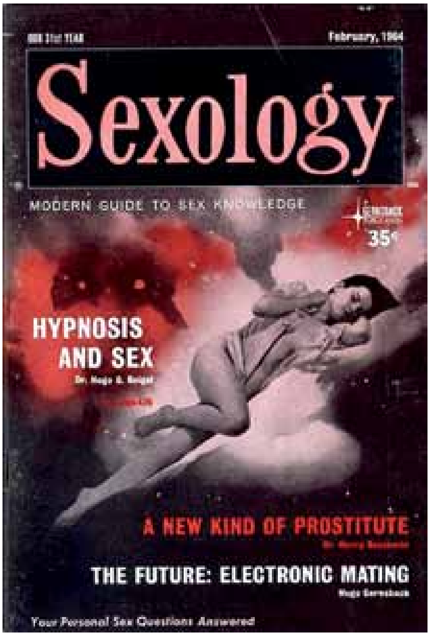
could be used to ring a bell, he was said to have marveled at seeing its effects, "The 'green spark' of the small self interrupting the contact of the bell."[3] And so influenced by that childhood experience, he relocated to America to become an electrical inventor and to no surprise, his first effort was the development of a new dry battery. He was able to create a business manufacturing starter batteries for the nascent automobile. Soon thereafter he was interested in the "companies in Germany and France, which supplied hobbyists and schools with physical instruments and components for experiments in the mail," and this resulted in his Electro-Importing Company.[4] This venture grabbed the attention of thousands of new radio amateurs who were eager to construct their new transmitting and receiving instruments. Even this author's previous work was touched by Gernsback's company. Early San Jose broadcaster and wireless school operator Charles Herrold was asked by Gernsback to endorse his products for his 1910 Electro Importing catalogue, and Herrold's notarized statement is cited as "proof" of early broadcasting for an audience writing, "We have given wireless phone concerts to amateur wireless men throughout the Santa Clara Valley."[5]

Along with catalogues, his wireless and electricity interests resulted in dozens of publications, starting with his April,1908 *Modern Electrics*. In April, 1926 he published the first science fiction magazine, *Amazing Stories*, with articles contributed by

Fig.6. EI catalogue (credit: Franz Pichler).

Wells, Verne, and Edgar Allen Poe. We can also assume that he was interested in sex for in 1933 he introduced *Sexology*, promoted as the "Magazine of Sex Science," which contained such articles as "Sex and Youth," and "Petting is Dynamite." In his lifetime he was credited with the publication of over 50 titles. One of his lasting legacies is the science fiction writer's award named for him, the "Hugo Awards." According to the official Hugo Awards Web: www.thehugoawards.com "The Hugo Awards are named after Hugo Gernsback, a famous magazine editor who did much to bring science fiction to a wider audience. Gernsback founded Amazing Stories, the first major American SF magazine, in 1926. He is widely credited with sparking a boom in interest in written SF. In addition to having the Hugo Awards named after him he





Figs.7–10. Various wireless and non-radio Gernsback magazine covers (Pichler, et.al.).

has been recognized as the "Father of Magazine SF" and has a crater on the Moon named after him." [6]

Gernsback Finds His Métier

But it was his 1919 premiere of *Radio Amateur News*, later re-titled *Radio News*, that through editorial opinion and selection of writers and content he set out to document and influence the evolution of radio. During radio's important development years, 1919 to 1924, he chronicled radio's move from earphones to loudspeakers, from hams to citizen audiences, from crude home made devices to store-bought working radios, and from two-way communication to music and news programming. Part of this rapid change was due to the great improvement in the science of the radio, much of it driven by the World War I patent pool, a government-forced "cooperation" of inventors and their patents for the allied war effort.

As the largest of the radio-themed consumer publications, *Radio Amateur News* began at a time when an eager audience of young men were returning from the war in Europe, many seeking their future careers. Gernsback would be their voice with a combination of articles, editorials and advertising. In an article in the July, 1919 issue, "The Audion and the Radio Amateur," Lee de Forest promotes himself, his history as an inventor, and attempts to position himself as a friend of the ham. He touts the amateur hobby as "The most wonderful thing ever thought of by man." What is left unsaid is that under a

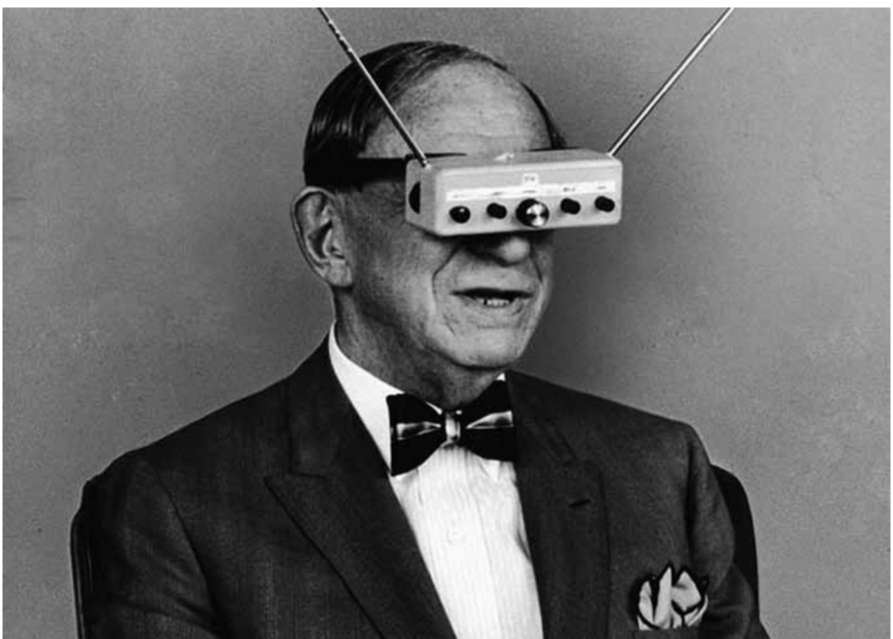


Fig.11. Gernsback with sci fi glasses (CHRS Library).

series of court rulings, de Forest is only allowed to sell his tubes and radios to the amateur, not the commercial user. So in this "amateur" publication, de Forest was writing for his market. That Gernsback respected, was even in awe of Lee de Forest, is evident in the many dozens of issues featuring de Forest, including his first serialized biography. De Forest was apparently allowed carte blanche by Gernsback to write and promote the de Forest products and inventions. Wrote de Forest in his July 1919 article about the benefits of his Audion, "forces of which Faraday himself never dreamed; etheric voices infinitely more delicate than the faintest sounds from Aeolian harps of the fairies. Invisible messengers, speeding like light, through the darkness come whispering to him directly from the antenna of some gigantic station."[7]

In the September, 1919 issue, a Gernsback editorial bordering on snarky introduces one of his frequent arguments against government control of radio: "We had thought that Government radio control was at a rest for a while when certain radio bills were defeated last year. It seems, however, to be a favorite pastime in Washington to sponsor Government Control of radio every month or so, at least that's how it looks to us."[8] He went on to argue that the "Radio Act of 1912 has been found ample for all requirements, be

6 RADIO AMATEUR NEWS July, 1919

"The Audion and the Radio Amateur"

By DR. LEE DE FOREST

Written especially for "Radio Amateur News"

THE writer can lay claim to the honor of having been one of the original wireless amateurs in America. When he started experimentting in 1898 and '99 the Art itself was very amateurish, from the Rhumkorff coil transmitter to the coherer and trembler of the receiver; while the ranges that were then covered were small enough to have satisfied the most jealous guardian of governmental radio-regulations, had such a functionary then existed.

It was not until 1902 and by the introduction of the self-restoring detector and telephone receiver, the alternating current generator and transformer, and the tuned circuits at transmitter and receiver, that the infant art can be considered as placed on an engineering foundation.

The first two of these radical advances originated in America, and for some time distinguished the American designed apparatus from that of the British or the Boche.

The story of the original conception of the Audion idea, using heated electrodes and ionic or

forces of which Faraday himself never dreamed; etheric voices infinitely more delicate than the faintest sounds from Aeolian harps of the fairies. Invisible messengers, speeding like light, through the darkness come whispering to him directly from the antenna of some gigantic station

First, there are the plain detector arrangements, with and without a grid condenser, with or without a grid or *C* battery. In the old days when the lamps were exhausted with simple oil-pumps, we had the fascinating "blue glow" or halo around the plate or filling the bulb, when a too-high *B* voltage was applied. Gradually the pumping processes have been improved until now the ordinary well built audion contains too little gas to show this visible and beautiful evidence of ionization. With the blue glow, however, a host of fascinating experiments can be made, such as the effect of a magnetic field on the glow and on the sensitiveness and general behavior of the audion — the "squealing" condition, the unstable condition when a blue ball plays around a corner of the plate and comes and goes with each strong received Morse signal —like a veritable little blue imp dodging back and forth in instantaneous response to his mas-

A Picture to Make the Heart of Any Radio Man Swell. The Inventor of the Most Wonderful Thing Ever Thought of by Man, in His New York Laboratory. Look, Ye Radiobugs! The

Fig.12. de Forest article page, Radio Amateur News, 1919, (CHRS Library).

they Government, commercial or amateur."[9] It is a year after the war's end, and it was the Navy and its Secretary Daniels who believed that their branch of the armed services used radio best in the allied victory and thus should retain control of radio in peacetime. It was fought over in Congress and quickly solved. Radio would become government licensed and regulated under the RCA agreements which specified which manufacturers would make radio transmitters and receivers, engage in "toll" and "chain" broadcasting. What was not clear was what radio would become beyond "a commercial service," whatever that meant.

De Forest returned to the pages of this issue in an article, "Reviewing American Radio History." In it he examines the great moments in invention and mentions the contributions of Fessenden, Marconi, Poulsen and himself. Missing from the list is E.H. Armstrong, de Forest's lifetime nemesis. In the article he does credit the Wright Brothers for their role in aviation and contributions to the allied side of the war, and he cites the pre-broadcast contributions of Marconi, Fessenden, Stone and many others, and as in previous articles in *Radio Amateur News* he writes for the amateur reader: "Of course, the greater distances covered by our best apparatus in those early days, say in 1903, were very small compared to those which are covered today by many a smart amateur's set. The average boy's wireless set today contains a far more perfect instrument than the most elaborate station could boast of in those pioneer days."[10] Here was de Forest writing in 1919 about the great leaps in technology since 1903, a mere 16 years! Think of where computers were 16 years ago with Windows 98 and AOL. Back then a tablet was something you wrote on with pen on yellow paper. A telephone you dialed.

Gernsback now begins, almost monthly, to proffer previews and prophecies of possible programming genres. In this same September, 1919 issue Gernsback wrote an article, "Grand Opera by Wireless." In 1919 the older word "wireless" is still used interchangeably with the newer designation of "radio." In this predictive article he suggests that opera music could be sent into homes using radio (not a new idea), and that the reason this is not being done now is that "no means has been found to reimburse the opera companies for allowing everyone to listen in." He writes: "During the next few years it will be a common enough experience for *an amateur* to pick up *his receivers* between eight and eleven o'clock in the evening and listen not only to the voice of such stars as Caruso, Tetrazzini, McCormack and others, but also the orchestra music as well, which is picked up by the sensitive transmitters along with the voice of the stars."[11]

Whether or not he realizes it, it is by his choice of words that he completely describes the proverbial fence on which he is sitting at the end of 1919. On one side is the known world of wireless messaging and developing technology and on the other a radio

Fig.13. Radio News cover, Grand Opera by Wireless (CHRS Library).

future mostly unknown. To deconstruct this passage: First, he refers to the audience as "an amateur" because that is the 1919 frame of reference, and he also uses the pronoun "his" as wireless is still a hobby dominated by the young male. Next, he describes the listening device as "receivers," as the state of the amateur technology in 1919 was the telephone earphone rather than the newly invented loudspeaker. It would be several years before the common crystal set would benefit from the amplification of the vacuum tube, allowing the horn-amplified headphone loudspeaker to come into common use. Sure, many inventors had already sent various forms of live and phonograph music over the air prior to 1919, but without technology that appeals to a consumer audience, and without the possibility, pre-war, of licensing new forms of commercial fare, it was not taken seriously. But you can see in the Gernsback article how his view of the past is influencing his interpretation of the future. He seems to be saying, "what if," but his prediction is still clearly and firmly rooted in the current 1919 model, radio as an amateur boy's hobby.

Then there is Gernsback the businessman musing editorially about what a possible grand- opera-by-wireless model might resemble. As a man of both theoretical and practical bent he wonders: "But we must give a thought to the management, which cannot subsist on an empty opera house if everyone could listen into the actual rendering of the opera without paying for the privilege. Needless to say that the producers would soon find themselves bankrupt."[12] He offers an idea which is a cross between to adopted by professional sports, originally called the blackout rule, and a Sirius-XM subscriber model: "Probably the only logical way out would be for the management of a grand opera company to advertise in the newspapers, stating that no grand opera via radio would be given unless a certain amount of revenue were guaranteed by radio subscribers before radio performance would be given."[13] As Gernsback is straddling the old way of wireless and the new way of radio for the masses, he is also keenly aware of what it takes to sustain a business when entering unknown markets. He will make this argument later about recorded music, purchase versus broadcast.

Gernsback continues his opera-as-programming predictions with these

Fig.14. Close up of crystal detector (author).

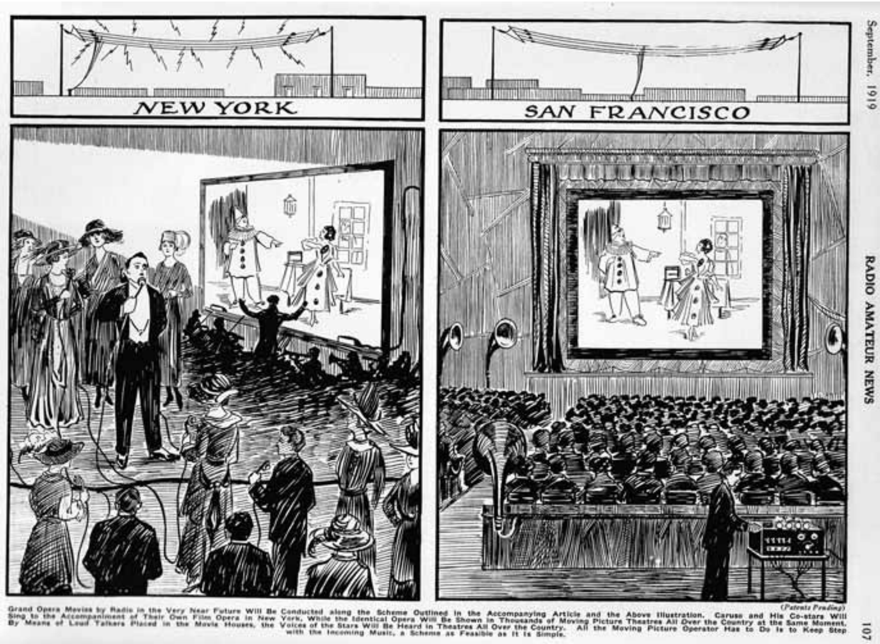


Fig.15. Opera drawings from RN article (CHRS Library).

illustrations of how it might work technically, again using the only model he knows, that of the existing media. And what he ends up with is a hybrid of radio and the silent film, suspiciously a television-like system, but in 1919. It is his idea that the opera company performing on a New York stage would have their performance filmed by the silent movie camera. The film would be processed and duplicated. A copy of it would then be screened on the opera stage while the opera singers and musicians would perform it in synchronization with the silent film. Read this slowly. The live performance would be picked up by radio microphones and broadcast to San Francisco where a radio receiver and loudspeaker would be set up next to a movie screen. On it would be projected a copy of the opera silent film. This film would somehow have to be synchronized with the received live performance audio. Yes, it could work, and said Gernsback, "The underlying idea is not only to give grand opera by wireless, listen to the music and to the singers only, but to actually see the operatic stars on the screen as well." Television? The Talkies? Remember that Lee de Forest by 1919 had submitted a patent application for a sound-on-film process and had often written about opera as content for radio and film.

The Future of Radio is the title of the Gernsback editorial in the October, 1919 issue of the still-named *Radio Amateur News*. Make no mistake, this is all about the evils of Government control and Publisher-Editor Gernsback pulls no punches in his loud voice in favor of getting Government off the backs of the radio suggesting: "a stupid and narrow humanity was ever ready to step in and command a threatening *Halt!* to scientific exploits . . .No sooner has the new art demonstrated its inconceivable boon to the world than some well-meaning but misguided official steps up and frantically tries to shackle it down, hands, body and feet. We ask ourselves with horror what would have happened to our telephones if our Government had taken control of them in the early eighties, as was the case in most European countries."[14] Clearly Gernsback is fuming and you can indeed see the steam pouring from his ears. He continues: "We are certain that if the men who now advocate Government Radio control were possessed of but a little vision as to the marvelous future and possibilities of Radio, they would recoil with horror at their preposterous suggestions."[15] Take that Washington! But in a "say goodnight and leave them wanting more Hugo," he continues his editorial by promoting a certain future for Tesla's Radio Power Transmission, "He was able to light lamps hundreds of feet away without the use of wires, using only a ground connection."[16] The next month's issue brought news that the formerly-evil Government had indeed lifted the ban on transmitting by amateurs. The Government and Navy Department would not control radio after all.

In early 1920 the magazine still contains the word "amateur" in the title, but there is yet another dichotomy on page 612 of the May issue. At the top of the page is an article, "Dancing by Radiotelephone," describing how couples can now dance to concerts of radio music, something that might describe radio as it is known today, but with one major difference: "As will be noted, each young man and his dancing partner are equipt (sic) with a pair of radio receiving headphones and connecting cords suspended from various parts of the room, thus enabling them to cover a considerable part of the floor."[17] Dancing with headphones, while probably not practical due to the obvious cord entanglement, does demonstrate two things: First, it is a novel use of the technology and potential programming then available, but second, for the first time a radio activity lets in a heretofore ignored part of radio marketing, the "dancing partner," a woman. This will be a necessary part of the new radio audience. The second article on the same page, "The Latest in Crystal Detectors," shows that we remain, at least partly, in radio's past.

The Transition is Complete

What a difference a masthead makes. Perhaps more than symbolism, by July, 1920, the title of the magazine is changed to reflect the now likely coming of the entertainment and information uses of radio by a non-amateur public. No longer only paying homage to the amateur, the magazine will remain as just *Radio News*. It is also a perfect time, thinks Gernsback, to predict the far radio future under the

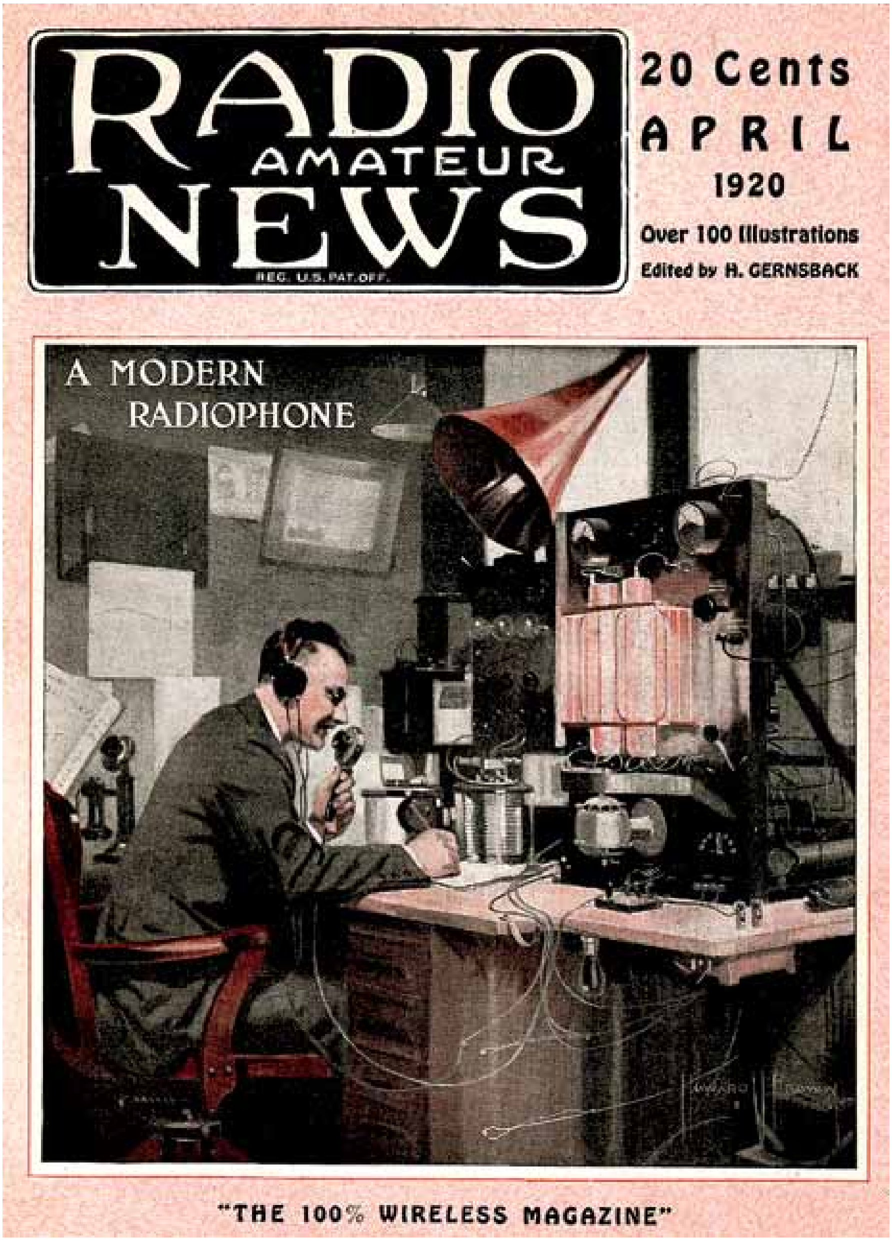


Fig.16. April, 1920 cover with word "amateur" in title (CHRS Library).

editorial title, "Radio in 1945." His predictions are not very daring. About 1945 he writes, "We will no longer need an aerial and ground wire," and "We will have loudspeakers." [18] Is that it? And as he continues to flail around for predictions of radio's technical future, his August, 1920 issue tells another story by its cover design. The theme, "Radio Music at Asbury," is illustrated by a strange three-wheeled wicker wagon being pushed by a uniformed porter along an ocean boardwalk (Atlantic City?). This image speaks volumes about the still confusing nature of broadcasting. In 1920, the radio takes up most of the space in the wagon, its giant loop antenna its prominent feature, and the listeners must still wear headphones. But the telling part of the image is not the technology but the audience: No longer will we see covers of young amateur boys creating sets, rather we will see as in this image the father, the mother and the child. In this picture it looks like broadcasting will arrive and it will be for the family. [19]

The editorial in that August, 1920 issue was a bit of deviation from radio concerts and broadcasting for the public. Titled "Radio Photography," it described a German experiment that was a precursor to the "wirephoto," a device that scans a picture and transmits it to a similar scanner at the receiving end: "At the sending end a picture or drawing is usually made upon tinfoil or any other conductive surface, the picture being printed in an insulating ink. We rotate the cylinder upon its axis while a metal stylus presses upon the tinfoil." [20] He compares this process to a needle reading a phonograph record, but explains it in telegraph terms: "The stylus and the metal cylinder, upon which the tinfoil is wrapped, are connected to an electro-magnet and battery so that it will operate an ordinary telegraph key, then in that case the key will be depressed every time the stylus touches the tinfoil and will likewise be released every time the stylus travels over the insulating ink. From this it will be seen that short or long impulses are sent out from the radio station all depending upon the physical makeup of the picture." [21] This would yield a very low resolution image, less than that of the 60 line "Felix the cat" of early Jenkins television. Even Gernsback admits that synchronization between transmitter and receiver would be nearly impossible. This is what he does through his magazine – reports and comments on possible new electronic technology.

But he does continue to give the reader solid predictions, like the September, 1920 editorial, "Radio Concerts." He tells the story of a British experiment, the sending of a performance by opera singer Madame Melba using radio. He is suggesting correctly that music might become the basis for the new service: "There is nothing that popularizes radio more than a concert by a famous singer, and it is to be hoped that our amateurs, as well as professionals, shall band together and try for some original ideas." [22] Notice again that the rapidly changing audience is causing Gernsback to focus some of the magazine's content toward a broader

Fig.17. RN cover leaves out "Amateur," Radio Music at Asbury (CHRS Library).

non-amateur reader. He is straddling the past and future when he refers to "amateurs" and a not-quite-clear "professional," as the originators of new programming ideas. He is not absolutely clear about the future role of the amateur operator, he does not want to leave them behind, and he probably sees music and news programming being developed by these unknown professionals. He does offer a caveat about an important part of this British experiment. The opera singers performance was captured by a receiver and recorded onto disc, he calls "the idea of catching the voice of a great opera singer by radio."[23] But Gernsback warns: "The point we want to make here is that, although America is supposed to be a country bordering close to the radio millennium, and, although there are practically no restrictions and the law is all with the amateurs, progress, as far as radio telephony is concerned, is negligible."[24] In this editorial he is exhorting America to come up with a form of music programming because we are behind, he says, the UK: "Of course there are many radiophone sets in the United States now, and these are growing all the time, but there are very few big 'stunts' that come to one's notice."[25]

He continues throughout 1920 to try hard not to alienate his core amateur audience while he suggests some grown up ideas better handled by someone of experience and creativity, perhaps from print media, a businessman even: "Why cannot someone go after the Presidential candidates and invite them to make a speech via radio thru a powerful telephone apparatus in the near future? With proper advertising and with the proper enterprise behind such a scheme, it certainly should not cost a great deal to do. The people of the United State, through the amateurs, would get a chance to listen to our candidates in a very novel manner."[26] There is that reference again to "amateurs," and surely Gernsback knows that they will not be the ones to drive the rapidly evolving future of radio programming. This is the most exciting time for radio. He summarizes with a call to action: "Of course, there are countless schemes and ideas of a similar nature, all of which make it possible to popularize radio, and that is what we are after. Now, why don't we get together and do it?"[27] This is Gernsback the cheerleader, sensing an opening for a programming format that will appeal to the public—and therefore sell radios and radio magazines and magazine advertising.

Also consider the larger perspective here: Students of media history must have some vague image of the KDKA experiment, called in their textbooks the first commercial broadcast, of the election returns programming of November, 1920. But starting with *Radio Amateur News* in 1919 there was a constant stream of ideas and news about how a post-amateur radio service might operate. There were many stories about how unknown audiences might hear opera or presidential campaign speeches, all of this before KDKA. This is the larger perspective,

Fig.18. RN, Oct, 1920 cover (CHRS Library).

and it demonstrates through several years of publications like *Radio News*, that the transition from young men building crystal sets to broadcasting in America occurred over a two or three year period, surely not overnight. And the radio story must be layered over the story of the economic and social transition from the darkness of an all-consuming world war to the very bright and loud 1920s. This author suggests that the technical needed a receptive social milieu to succeed.

In the October, 1920 issue, there is an article featuring an idea that to the 21st Century reader/historian may seem like something it is not, and that is the idea of news by radio. Seeing the cover and reading the title, "Reporting News by Radio," you immediately see the intrepid reporter on the scene, in this illustration a fire, and you can picture the home listener leaning into the radio as the story unfolds. Right? Wrong. The reporting of news is still 100% the domain of the print industry, and as the story reports, "We may thus conjure a newspaperman reporting a big fire, or a big flood, or a railroad wreck or any other dire calamities, by pressing a button in his pocket and talking through a small mouthpiece with his city editor downtown." [28] This is not radio news as we know it, but it is a reporter using the radio to send content to a man with a typewriter who will write a story for a print "extra," and get it on the street quickly. We are still in the past, the known world, even as we contemplate the future of an unknown media format, broadcasting news by radio. Also note another artifact of the past, the telephone microphone used by the reporter. That carbon microphone would remain a staple of radio broadcasting throughout the 1920s, just as the magnetic telephone earphone would be the basis for radio headphones and the horn speaker of the early 1920s.

The November, 1920 editorial is titled "Fool Ideas," and in this writing Gernsback tries to suggest that maybe the vacuum tube is not the last word in detection or amplification. He is asking readers to consider more advanced uses of an old friend: "Is it impossible to take a crystal detector and make an amplifier out of it? Is it not possible to devise some means whereby the sensitiveness of the crystal detector can be amplified similarly as the vacuum detector is amplified? This is, of course, only an idea, and the writer does not know how it can be brought about, but it certainly should be possible." [29] A slow news day? Perhaps, but while the reader of today might get a laugh out of this sort of technical pretzel, consider that the crystal diode is really just an early semi-conductor, and who today sees the vacuum tube as the future, save for its renaissance in high end high fidelity and guitar amplifiers. In Gernsback's world, it may be that he is engaging in "throw it against the wall and see what sticks" journalism.

In January, 1921, *Radio News* begins a series of profiles of radio stations, and in this issue, the experimental but never commercially-licensed de Forest California Theatre San Francisco station under 6XC is featured. De Forest had been on the air since early 1920, at least six months before KDKA, which also started as the experimental station 8XK. Note that this issue features on its cover a photo of a young man operating a radio, "listening in" using headphones, while his grandma who is knitting nearby seems not to pay attention. And at the bottom of the cover it still says "The 100% Wireless Magazine." Again, this is Hugo Gernsback with one foot in the past while trying to predict a future for radio. A year goes by, KDKA and hundreds of other station are now on the air, and it is obvious that the radio is going to be an important part of post-war America.

By the December, 1921 issue he begins to put it all together in a cover story and editorial titled, "The Radiotrola," a convenient marriage between the radio of amateur times past with the victrola now found in most homes. He writes: "To the careful observer, during the past six months is has become apparent that we are finally headed in the right direction as far as popularizing radio is concerned. We may say that we are right in the midst of a revolution, as far as radio and the great public are concerned."[30] This is almost one year after the famous KDKA election broadcast on November, 1920. Gernsback now sees a revolution driven by music programming. He also sees that it will be more than his original audience, the young man as amateur operator and set builder, and he cites his mail as confirmation: "The editor's desk is beginning to become flooded with letters, not from radio bugs alone, but from the layman, who does not know the difference between a detector and a telephone receiver – all of which is a healthy sign, and we may say that radio is entering into its last and final stage, as far as the public at large is concerned."[31] Finally, the transition is complete, amateur to broadcasting. Advertising in this issue features a two-tube radiola for $35 dollars, and a Radiola loudspeaker that is "clear as your headphones."

Broadcasting Matures

By 1922 the radio business and its art was nearly fully formed, and these early years will become known as the "Boom Years" in radio. Gernsback is now urging radio manufacturers to quit making poor quality radios or risk a radio bust and loss of consumer trust and business. He is also suggesting that radios must become more consumer-friendly, a refrain heard about the personal computer: "Indeed, radio engineers, as well as the entire technical fraternity today, bend every effort towards simplifying every radio set to such an extent that it will come into the class of the phonograph or the automobile; that is, that the owner does not need to know anything of the radio whatsoever in order to operate his set."[32] This is likely an industrial model that is followed today, culminating in the smart phone or tablet computer that anyone can operate without a knowledge of the computer inside.

So now that programming ideas have been considered, tried, rejected or accepted, and the evolution of the radio from wireless and hobby to a consumer must-have invention are nearly complete, there are other issues to be debated and decided upon. In August, 1922 Gernsback publishes this article by JC McQuiston, "Advertising by Radio, Can it and Should it be Done?" In this article, it is believed that advertising will ruin the radio business, and that ads will destroy the public service that radio can become. But the article's author, a publicity manager at Westinghouse, understands why it might happen: "Radio now takes the place of both weather and health as the chief subject of conversation, It is no wonder that just as soon as the public recognized the use of radio, advertisers gave consideration to this wonderful agency for spreading selling information."[33] Not necessarily an editorial viewpoint, the writer urges careful consideration of what we now accept as radio advertising. But in 1922, there were several schools of thought about advertising, with one of the earliest by the author's employer, Westinghouse. They believed that the sale of radio receivers would pay for the service much like the "Radio Music Box" idea advanced previously by David Sarnoff. Radio luminaries like Lee de Forest wanted radio to be operated purely as a public service, his goal to get great music into the homes of what he would call the common folk. So the question, "will radio advertising happen and will it be effective?" was asked and answered in many ways. It is a question that is still being asked today about every new media – how will we pay for it? Radio then was like Facebook and Twitter today, hugely popular but with underlying questions about long term viability, and experimentation with various models of paying for it. Like radio, Facebook for many is a "public service," free to the user, and its ads are not always effective. Can this last? No one knows. In the 1920s radio, like Google today, quickly became a leader in the then new economy.

The June 1923 cover and main editorial was titled "Broadcast Listeners Number," and featured a young woman "tuning in" and wearing the still popular headphones. By now the future of radio was easy to predict, but Gernsback reminds us anyway: "The broadcast listener, as we all know, is in a distinct class by himself. He is not interested in the technicalities of either electricity or radio at all. He buys a radio set for one purpose only—to listen in."[34] In this editorial Gernsback raises a number of issues about the future of the radio. He prods manufacturers to make simpler sets. And while he could not predict it, by the mid 1920s, a listener could tune a radio by manipulating only three knobs, and because of the vacuum tube amplifier, your entire family could listen to it on a horn speaker, really an earphone acoustically enhanced by a plastic horn. By the end of the 1920s you could buy a radio with one knob tuning in a wood furniture-like cabinet, and the paper cone loudspeaker would give a truer reproduction of voice and music. Gernsback also alluded to the fact that in 1923 not all areas were served by a station, but this too was changing rapidly. Prior to the time the Radio Act of 1927 was passed, there were hundreds

Fig.19. RN June, 1923 cover, Broadcast Listener Number (CHRS Library).

of stations on just a few frequencies, all interfering with each other. Resolving the resulting cacophony was the main purpose of the Radio Act.

Lee de Forest makes one of his many visits to the pages of *Radio News*, and it was surely symbiotic for both him and Gernsback. De Forest was forever associated with the development of popular radio, and his name would surely sell magazines, just as de Forest was manufacturing radios to take advantage of the exploding mass entertainment media that was broadcasting. So with great fanfare in July, 1923 de Forest introduced radio fans to his Flame Microphone. This would have to be dangerous, a live gas flame, but he believed that it would solve one problem of the now aging and low quality carbon telephone microphone currently used in broadcasting. Wrote de Forest of the device: "Sound waves in air are translated directly into electrical energy through a flame, without vibrating diaphragm."[35] He makes the case for the problems of the diaphragm: "Efforts of telephone and phonograph engineers have been devoted to reducing as far as possible distortions thus introduced by the natural period of vibration of the diaphragm, or membrane, against which the sound waves impinge."[36] For this device he has used a Welsbach oxy-acetylene flame and inserted two heat resisting electrodes connected to an amplifier: "You will then have an extremely sensitive sound converter which gives an electric reproduction of the sound waves in the air enveloping the flame which is of an entirely different order of fidelity from that ever obtained from any form of microphone device, using a diaphragm, whether this be of the carbon, electro-magnetic, or electro-static variety."[37]

As a scientist de Forest always began with the theory and then attempted to translate it into practice and patent and profit. It can be imagined that the so-called "air talent" who would be speaking into this microphone would be wary of a live flame so close to the mouth. With this article he also solved another problem existing in the de Forest world. Since 1919 he had largely abandoned tubes and radios, all of these mired in various court cases, and for the past years he had spent all his inventing time on Phonofilm, his sound on film device that he hoped would change Hollywood. This article for *Radio News* mentions prominently that the flame microphone was developed for the Phonofilm, a fact he mentions three times in the opening paragraphs. The idea of a flame in an acoustic environment is not new. This author has found in the literature a story of an experiment using a Poulsen arc as a public address system, the carbon microphone and DC source coupled through a transformer to a DC arc, and the vibration of the arc being amplified using a large horn. The quality must have been marginal at best, likely unusable as it never surfaced again. Reports said it was loud.[38]

By 1923, live and recorded music has become the content foundation of the new radio media, and just as the public and industry have witnessed throughout the years, the artists and publishers fight broadcasters for copyrights and fees. In one corner is the new kid radio, believing that if it airs the music, live or recorded, the artists will sell more sheet music or records because of the exposure. In the other corner it is the artist who argues that if radio plays it for free, the public will not buy the music or records. Says Gernsback in his September, 1923 editorial, "Music vs. Radio," "The whole country has been watching with interest, and we believe with considerable annoyance as well, the fight between the music publishers and authors, conducted against radio broadcasting stations. The controversy in brief is that the music publishers and authors insist that the broadcasting stations pay them a royalty on their music compositions, and until this payment is forthcoming, they refuse to let the broadcasters use their music. They claim this right under copyright law."[39] This issue was resolved then by a fee structure and recently re-litigated for streaming music via the Internet. That this argument took place in 1923 is evidence that radio had arrived, was popular, had great influence, and like all media must pay its way to remain in the consumer's life. These arguments over live and recorded music would be followed in the next decade over newspapers being read on the air with the same argument, will reading a paper over the air for free keep readers from purchasing the actual print edition? This issue is again alive as today the major newspapers started by giving away their paper on the Internet, and now they are trying to monetize their

Fig.20. Later Gernsback media magazine (Credit, Franz Pichler, CHRS).

Fig.21. Later Gernsback media magazine (Credit, Franz Pichler, CHRS).

journalism and make enough money to pay their reporters.

By 1924 Gernsback wrote that the radio boom was over. Radio was successful, and so was his most important publication, *Radio News*. He had brought his large audience of magazine readers the news and his opinions of what it might mean, beginning with his wireless publication *Modern Electrics* in 1908, leading to *Radio Amateur News* in 1919, changing that title to *Radio News* a year later. He was the major news force in the transition from the wireless hobby to broadcasting for the public. Into the 1930s and 1940s Gernsback introduced *Radio Craft*, *Short Wave Craft*, *The Experimenter*, *Television News*, *Science and Invention*, *Electrical Experimenter*, and later *Radio News* became *Radio and Television News*, with the focus of that publication toward the manufacturer and dealer of radios and televisions. He loved to write, he lived to influence his audience, and beginning in 1919 he pointed all of his editorial capital to predictions of what broadcasting by radio should and could do best. More than any writer of the era, Gernsback did report about, guess, predict, and promote radio between 1919 and 1924, its most formative years. His influence was significant.

Fig.22. Later Gernsback media magazine (Credit, Franz Pichler, CHRS).

Notes

This article appeared in a much abridged version in the Fall, 2012 CHRS Journal, and was the basis for the Author's Banquet speech at the 2013 AWA Conference in Rochester, NY. The scans of the Gernsback magazines are from Franz Pichler's Gernsback book, the author's collection and the Maxwell Communications Library of the CHRS Museum and Radio History Center in Alameda, CA.

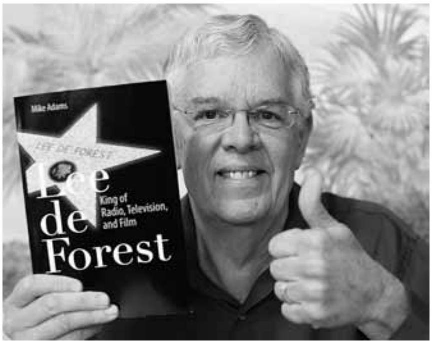
In my research, resulting in *Lee de Forest, King of Radio, Television, and Film* (Springer Science, 2012), I looked closely at the vacuum tube of de Forest and its important role as a detector, amplifier and transmitter. In my opinion, the tube was the most important single piece of technology responsible for modern radio, and Gernsback took advantage of that and used de Forest often in his publications.

1. George H. Clark, Radioana Collection, 1880–1950, Washington, D.C., National Museum of American History, Smithsonian Institution.
2. Hugo Gernsback, *Radio for All*, J.B. Lippincott, 1922, Philadelphia.

3. Franz Pichler, *Hugo Gernsback und Seine technischen Magazine*, Trauner Verlag, 2013. (Professor Pichler sent me a copy of his very well illustrated book written in the German language. I scanned the relevant text sections, put them into a Web-based OCR program, then put the OCR German text into Google Translate for an English version. These programs were free and the work was completed almost instantly.)
4. ibid.
5. Gernsback Publishing, Electro-Importing Company, catalogue, 1910, New York
6. The Hugo Awards Web, www.thehugoawards.com
7. Lee de Forest, "The Audion and the Radio Amateur," *Radio Amateur News*, July 1919.
8. Gernsback editorial, *Radio Amateur News*, September, 1919.
9. ibid.
10. Lee de Forest, "Reviewing American Radio History," *Radio Amateur News*, September, 1919.
11. ibid.
12. ibid.
13. ibid.
14. Gernsback editorial, *Radio Amateur News*, October, 1919.
15. ibid.
16. ibid.
17. "Dancing by Radiotelephone," *Radio Amateur News*, May, 1920.
18. Gernsback editorial, *Radio News*, July, 1920.
19. *Radio News*, August, 1920.
20. ibid.
21. ibid.
22. Gernsback editorial, *Radio News*, September, 1920.
23. ibid.
24. ibid.
25. ibid.
26. ibid.
27. ibid.
28. "Reporting News by Radio," *Radio News*, September, 1920.
29. Gernsback editorial, *Radio News*, November, 1920.
30. Gernsback editorial, *Radio News*, December, 1921.
31. ibid.
32. Gernsback editorial, *Radio News*, July, 1922.
33. J.C. McQuiston, "Advertising by Radio, Can it and should it be done,?" *Radio News*, August, 1922.
34. *Radio News*, June, 1923.
35. Lee de Forest, "The Flame Microphone" *Radio News*, July, 1923.
36. ibid.
37. ibid.
38. see Mike Adams, *Lee de Forest, King of Radio, Television, and Film*, Springer Science, 2012 for the complete Phonofilm story.
39. Gernsback editorial, *Radio News*, September, 1923.

About the Author

Mike Adams has been a radio personality and a film maker. Currently he is an emeritus professor of radio, television, and film at San Jose State University, where he has been a department chair and an associate dean. In addition to his work at San Jose State, Adams continues to teach classes at the Shanghai Theatre Academy School of Television and Film. As a researcher and writer of broadcast and early technology history, he created two award-winning documentaries for PBS, “Radio Collector,” and “Broadcasting’s Forgotten Father.” Mike is the Board Chair of the California Historical Radio Society/CHRS. For his service to historical radio he received the AWA Houck Award, the SCARS President’s Award, the RCA Ralph Batcher Award, the TCA Stokes Award, and he was named a CHRS History Fellow. He has had published numerous articles and four books, including *Charles Herrold, Inventor of Radio Broadcasting*, McFarland, 2003, and *Lee de Forest, King of Radio, Television, and Film*, Springer Science, 2012.



Mike Adams

General Electric's Early Transistor Radios

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Abstract

When commercial quantities of transistors became available in the early 1950s, incorporating them into consumer products was more difficult than simply removing a vacuum tube, making a few circuit adjustments and inserting a transistor. This article describes how the General Electric Company phased out vacuum tube technology in their portable radios over a period of 2 years, and then continued as a major producer of transistorized portable radios for the next 3 decades. The application of transistor technology was complicated by: shortages and process control issues with the early transistors; availability of miniaturized components; and tradeoffs between cost, size, weight and audio quality in their portable radios. Once these challenges were met, cost competition from foreign suppliers became an issue. How the General Electric Company met these challenges is the subject of this article.

Transistors Become Available

Following the Allied victory in Europe on May 18th of 1945 and the subsequent victory in the Pacific on September 2nd, the US economy rapidly began to convert from a wartime to a peacetime basis. Consumers eagerly began spending their savings on new houses in the suburbs, a new car, modern fashions in clothing and—at the top of their buying list—a new television set. As more and more homes owned a television set new programs and stars arose to fill the available broadcast slots. A new communications medium took the country by storm. Less noticed at the time were experiments at Bell Telephone Laboratories that ultimately produced a device in 1947 that amplified electrical signals without the use of a traditional vacuum tube. The transistor had been born.

From a laboratory curiosity in 1947, the new device rapidly evolved and began to be available in the early 1950s in quantities that could be used in consumer and military products. In their rush to apply the new device to their products, many manufacturers experienced a "learning curve" in its application. General Electric (GE) was no exception and this article will discuss the period that began in the early 1950s when the company was first applying transistor technology to its radios. As a note, this article does not delve into "What company or which individual, did what, first?" but rather, addresses the design and construction evolution experienced by a major producer of consumer electronics over a period of just a few years.

To provide an idea of the magnitude of the changes introduced by solid state technology, Figure 1 compares a state of the art GE vacuum tube portable radio of the early 1950s, to GE's first true transistor "pocket radio" of 1960.

GE'S Facilities and Product Nomenclature

Any discussion of GE's radio production should mention the several manufacturing locations that were involved. Prior to World War 2 GE's Consumer Electronics business (which included radios) were located in Bridgeport, CT—in a building dating back to the late 1800s that was originally the manufacturing plant for Remington Arms (Figure 2). The antiquated and cramped quarters were shared with GE's Housewares business and in 1942 planning began for a new facility. Syracuse, NY was selected as the location, and construction of the new facility, named "Electronics Park", began in 1945 with production beginning in the Receiver Building in 1948.[1] The Receiver Building, the large building in the upper right hand corner of Figure 3, had 14 assembly lines running the length of the building, 10 of which were devoted to television receivers, and 4 to radio receivers. However GE had underestimated the demand for television sets and it was soon necessary to move production of radios to Utica, NY. The facilities at Broad Street (Figure 4) were hardly more modern that those at Bridgeport had been, dating back to the mid-1800s—but at least they were spacious. GE's Radio Receiver Department

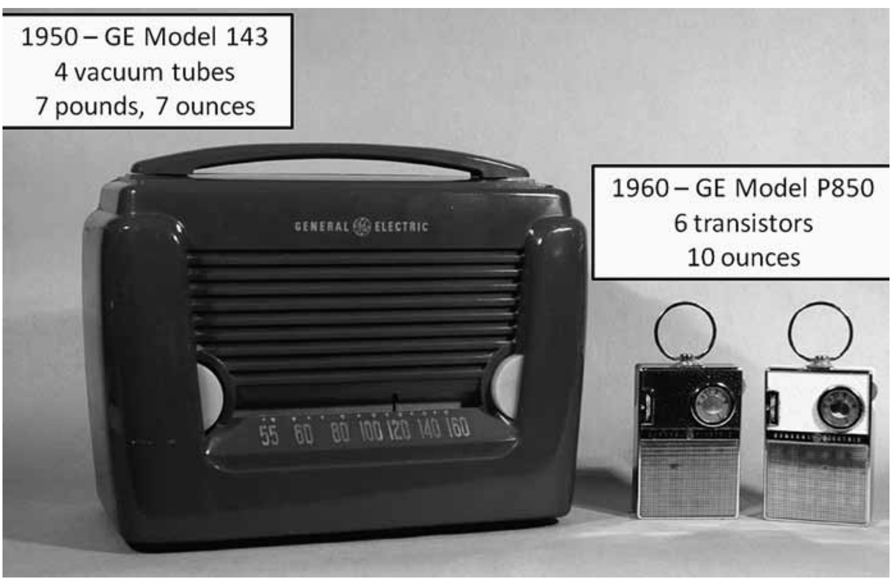


Fig.1. State-of-the-Art Portable Radios.

Fig.2. Bridgeport Facility.

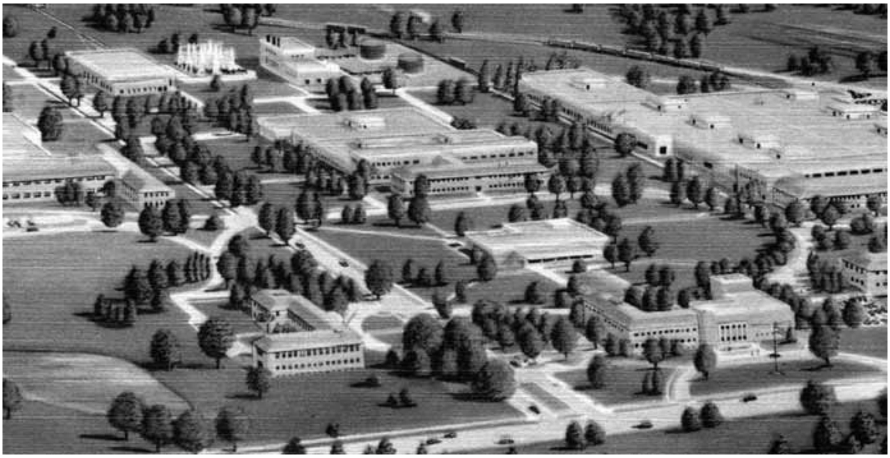


Fig.3. Electronics Park Facility.

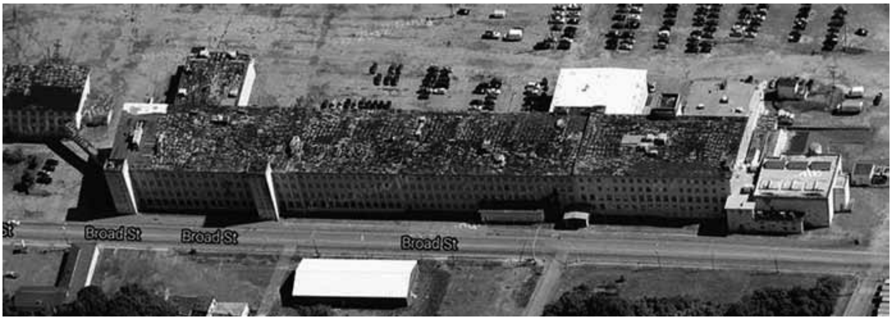


Fig.4. Broad Street Facility today.

operated out of these facilities and additionally those at Bleeker Street for many years, gradually downsizing in the 1970s when most production was moved offshore, until 1987 when the business was sold to Thomson S.A.

Thus GE's radios were produced at a number of locations during the immediate post-World War 2 years and the following sample models illustrate the shift of production from Bridgeport to Syracuse, and subsequently to Utica:

Model 250 (1946) – Bridgeport, CT.
Model 143 (1949) – Syracuse, NY
Model 604 (1950) – Syracuse, NY
Model 676 (1955) – Utica, NY
Model 666 (1956) – Utica, NY
Model P745 (1958) – Utica, NY
Model P851 (1960) – Utica, NY

A note on GE's nomenclature for its radios: the company used a number of different nomenclature schemes for the model numbers for their consumer electronics. Beginning in the mid-1940s numerical model numbers were assigned with the model numbers corresponding generally, but not always, to the order in which the models were introduced to the public, and with models with the same chassis but differences in the cabinet or housing being given sequentially higher model numbers. Thus GE's first transistor portable radio introduced in 1955 was initially available as models 675 (black housing) and 676 (ivory housing), and subsequently as models 677 (red housing) and 678 (green housing). In the mid-1950s the company changed to a scheme where model numbers for radios would be prefixed with a "T" for table radios, a "C" for clock radios, and a "P" for portable radios. The prefix would be followed by a three-digit number which, again, generally represented the sequence in which the models were entered production. As before, the same chassis used in different cabinets was handled by sequentially higher three-digit numbers. Thus, for example, GE's first full-sized transistor portable radio introduced in 1956 was available either as a model P720 ("ginger" leather cabinet) or as a model P721 ("champagne" leather cabinet).

Design changes during production were common for the early transistor radios. Prior to the new nomenclature scheme in the mid-1950s, model changes were designated simply as "early production" or "late production." But with the new nomenclature scheme, an alpha character was appended to the model number whenever a significant design change was made. Thus, for example, when a change was made to the biasing of the 2^{nd} IF stage in the model P720, the modified design was designated the P720B. These design changes were generally transparent to the public, being of interest mainly to those who had to repair or service the radios.

Design Challenges

GE's designers of these first transistor radios faced a number of challenges:

Component Size – Many of the components such as potentiometers, variable capacitors, IF, interstage and output transformers and loudspeakers were not at first available in the miniature sizes needed for the smaller set sizes, and that would later become commonplace.

Transistor Cost, Availability and Performance – Suppliers were not always able to meet demands for the various types of transistors being offered in the 1950s, thus parts shortages were a problem. In addition, some of the parameters of the early transistors were not well controlled. Beta, or common emitter current gain, (h_{fe}) is a good example, so designers had to anticipate and deal with this. And since process yields were low at first and producers were struggling to satisfy demand, prices for transistors were significantly higher than the vacuum tubes that they replaced.

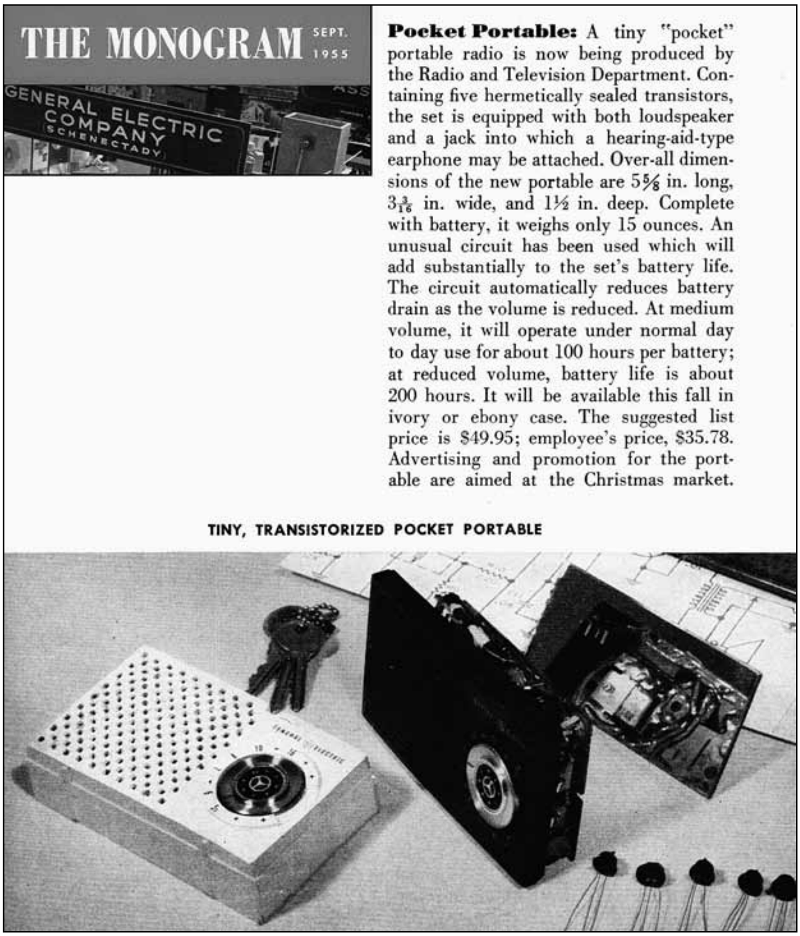
Battery Life, Cost and Size – By the mid-1960s, the small rectangular 9V battery as well as AA and AAA cells had become the unofficial standards for small transistor portables. But in the 1950s because of the constraints of device voltage requirements and battery life/size tradeoffs, supply voltages ranged from a low of 3V to a high of 13.5V and a number of different battery types and configurations were used in the early GE transistor radios.

In implementing the new technology, a company could produce a "full sized" transistor portable that was comparable in size to the vacuum tube portables of the era. This design would offer higher volume, better sound quality and longer battery life. At the other extreme were the "pocket" transistor portables that offered much smaller size and lower weight but at the tradeoff of lower volume, poorer sound quality and shorter battery life. And in the middle were the "medium" sized transistor portable radios that presented a compromise between the two extremes.

GE had publicized a number of different radio receiver circuit applications for their transistor products,[2] ranging from a diode detector followed by a single stage of transistor amplification, to a 6-transistor superheterodyne receiver with a push-pull audio output stage. But all of the early GE transistor radios used a superheterodyne circuit. These early transistor radios ranged from a 4-transistor circuit to an 8-transistor circuit with the major differences being the absence or presence of an RF stage, the number of IF stages and whether the audio output stage was single-ended or push-pull.

The following section of this article will begin with the introduction of GE's first transistor radio in 1955, discuss the challenges faced in its design, and then move through subsequent designs, discussing how the design and construction technology of the radios evolved over a 6 year period.

GE's First Commercial Transistor Radio 1955: Models 675, 676, 677 & 678 – These radios were promoted in an employee publication "The Monogram" (Figure 5) in 1955 as a "Pocket Portable". But at 5-5/8" wide × 3-3/16" high and 1-1/2" deep, and weighing 15 ounces, these models really fell somewhere between a real "pocket" radio and a full sized portable. This chassis used the 5-transistor circuit shown in Figure 6. A special battery provided supply voltages of 4.5 and 13.5 volts, and with a current drain of only about 5mA battery life was in the low hundreds of hours. Of course current drain and battery life were greatly affected by the setting of the volume control and playing the radio at maximum volume could cut the battery life in half. [3a, 3b, 4a]


THE MONOGRAM SEPT. 1955

GENERAL ELECTRIC COMPANY SCHENECTADY

Pocket Portable: A tiny "pocket" portable radio is now being produced by the Radio and Television Department. Containing five hermetically sealed transistors, the set is equipped with both loudspeaker and a jack into which a hearing-aid-type earphone may be attached. Over-all dimensions of the new portable are 5⅝ in. long, 3 3/16 in. wide, and 1½ in. deep. Complete with battery, it weighs only 15 ounces. An unusual circuit has been used which will add substantially to the set's battery life. The circuit automatically reduces battery drain as the volume is reduced. At medium volume, it will operate under normal day to day use for about 100 hours per battery; at reduced volume, battery life is about 200 hours. It will be available this fall in ivory or ebony case. The suggested list price is $49.95; employee's price, $35.78. Advertising and promotion for the portable are aimed at the Christmas market.

TINY, TRANSISTORIZED POCKET PORTABLE

Fig.5. GE's Announcement of Their First Transistor Radio.

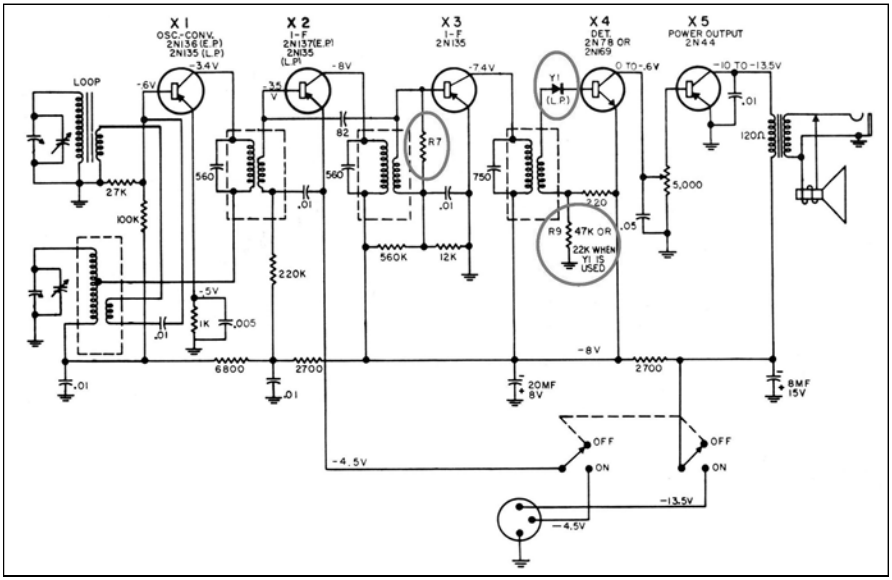


Fig.6. 675, 676, 677 & 678 Schematic.

Several circuitry changes were made during production. Early production models did not incorporate the Y1 diode, and the X4 transistor was biased to serve as a diode detector with little gain. Later production models added diode Y1, and resistor R9 was reduced from 47K to 22K to bias X4 to produce additional gain and more drive to X5, increasing the power output. GE's early production transistors were not well controlled for Beta (h_{fe}) [6]. The 2N135/2N136/2N137 transistors were manufactured on the same production line and individually tested for gain with the higher gain units (h_{fe} > 60) being marked and sold as 2N137's at the highest price, the medium gain units (h_{fe} > 40) being marked and sold as 2N136's, and the lowest gain units (h_{fe} > 20) being marked and sold as 2N135's at the lowest price (Table 1).

Table 1—Batteries Used in GE's Early Transistor Radios				
Voltage	**Size**	**Chemistry**	**Eveready Type**	**Price[1]**
1.5 volts	AA (0.6" diam. x 1.97")	Carbon Zinc	E915	$0.10-$0.13
		Nickel Cadmium	N46	$1.93-$2.00
		Mercury	E12	$0.82-$0.92
	C (1.03" diam. x 1.97")	Carbon Zinc	E935	$0.13-$0.17
	D (1.35" diam. x 2.42")	Carbon Zinc	E950, A100	$0.16-$0.36
4.2 volts	AA (0.6" diam. x 1.97")	Mercury	E133	$1.18-$1.32
9 volts	1" diam. x 1-15/16"	Carbon Zinc	226	$0.62-$0.95
	1-13/16" x 1-13/16" x 2-7/16"	Carbon Zinc	266	$1.05-$1.36
4.5/13.4 volts	1-21/64" x 1-1/32" x 2-11/16"	Carbon Zinc	E239	$1.05-$1.77

[1] **Retail single unit prices from Lafayette Electronics (1961), and Allied Electronics (1968) catalogs.**

To minimize the cost of individually characterizing the gain of each transistor, the company developed a piece of special test equipment. As transistors came off the production line they were placed in carriers which were then run through this equipment which performed a number of pass-fail tests and also characterized the gain of each transistor. The units that survived the pass-fail tests were dropped into different bins at the right-hand side of the tester according to their gain, and were then marked and sold with the appropriate part number.

Depending upon process yields and customer demand, some 2N135's might have a gain significantly higher than the minimum of 20, even as high as 40 or 60 in some cases. GE compensated for this by selecting the value of R7, the base bias resistor for the 2N135 used in the IF stage, to compensate for gain changes in the three stages employing 2N135's. A typical value for R7 was 470 ohms but the GE servicing information noted that, "Replacement of X1, X2 or X3 may require changing the value of R7." The suggested procedure was to temporarily replace R7 with a 500 ohm potentiometer, adjust the potentiometer to the highest value that would not cause "motorboating", and then select the next lower value standard resistor to replace the potentiometer. R7 was conveniently mounted on the exposed side of the circuit board where it was easily accessible to a technician during servicing.

These models used a very cramped housing and an explanation was provided in GE's service notes [3a, 3b] of how to grasp the front and back portions of the housing with two hands while simultaneously twisting and pulling to remove the back of the housing. Apparently GE was also a little nervous about the ability of some service technicians to deal with the new technology as their service notes redrew the schematic of these radios as a vacuum tube circuit to explain its operation. The service notes also cautioned that some new tools would be required to work on these radios, including a jeweler's loupe, tweezers and a low wattage pencil soldering iron.

As with later GE transistor portables, these models were considered "deluxe" models and accordingly priced at $50, as compared with the then-current pricing for GE's vacuum tube portables of about $40. Interestingly, once a GE transistor portable had been introduced, the prices of the GE vacuum tube portables still being offered immediately fell to $30, then to $25, and eventually to $20. In keeping with the image of a deluxe product, GE offered a carrying case for these transistor portables made of "Genuine Top Grade Cowhide" and priced at $15.

GE's Later Transistor Radios

1956: Models P720 & P721 – The size of these "full sized" models (10-1/4" wide by 7" high 3-1/3" deep), could be viewed as either an advantage or a disadvantage. The larger size allowed the use of conventionally-sized components which greatly simplified the mechanical design of the radio and minimized the procurement cost of the components.

Construction used a printed wiring board (PWB) on a conventional metal chassis along with considerable point to point wiring. A large 4" speaker and the Class B push-pull output stage shown in Figure 7 could produce nearly a quarter watt of audio. Power was provided by 4 "C" cells with a life in the hundreds of hours. In addition to longer operating life, the cost of the ubiquitous "C" cells was low. Figure 8 is an advertisement for this radio that promoted those features.

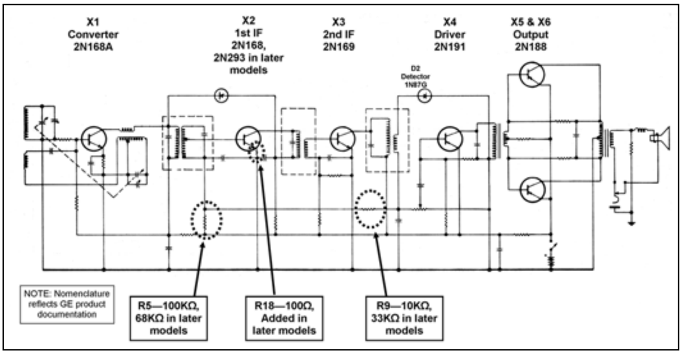


Fig.7. P720 & P721 Schematic.

Fig.8. P720 & P721 Advertisement.

Several design changes were made during production. The values of resistors R5 and R9[4a]. which set the bias for the second IF stage were adjusted. In addition, R18 was added in the emitter circuit of that stage. And in a change that presages GE's later problems with transistor availability, a 2N168 was listed as an alternate device in the second IF stage.

In keeping with their image as a premium product, the P720 & P721 also had a "Top-Grain Cowhide" housing as contrasted with the molded plastic cases of GE's vacuum tube portables. And these transistor portables were priced at $60—a significant premium over their vacuum tube portables.

While not especially remarkable in itself, the P720/P721 gave GE a basic full size transistor radio design that could be easily, and inexpensively, evolved into a number of new models later in the 1950s: the P725/P726 in 1957; the P750 in 1958; the P760/P761 in 1958 and the P795/P796/P797 in 1959. The P720/P721 also served as the basis for three additional "higher end" radios that offered an RF stage and/or additional IF stages and improved audio quality: the P770/P771 in 1959; the P776 in 1959, and the heavyweight (11 pounds) P780 in 1959 which incorporated a large 5.25" speaker. Beginning with the P720/P721, GE continued to offer large transistor portables with high sensitivity and good audio quality through the GE AM/FM Superradio series into the early '90s.

1957: Models P710 & P711 – These models were GE's second generation of small transistor portable radios. From the model number, it might be reasonable to assume that these models would have been introduced a year before the model P720/P721 was introduced in 1956, or at least in the same year, but in fact they were released one and three years later respectively. The reason for this appears to be that this radio incorporated a "reflex" circuit and the added complexity of this circuit, plus several design changes to improve audio quality delayed its production

Figure 9 which shows the schematics for the P710A/B/C series [4a] is helpful in understanding some of the problems faced by the designers of this radio. Remember that this was before the "transistor wars" of the 1960s where engineers packed more and more transistors into their radios (even if they were used only as diodes) so that their advertising could trumpet the large number of transistors. One of the constraints on this model, however, was to keep down cost and size and this translated to reducing the number of transistors. To us today, the cost of a transistor seems inconsequential but in the mid-1950s the early transistors were very expensive. Not only were transistors much more expensive, but because of the limited supply radio manufacturers had much less negotiating power to obtain volume discounts.

To pack 5-transistor performance into a 4-transistor radio a reflex circuit was used where a single transistor was used both for the 2nd IF stage and the 1st audio stage. As shown in the schematic for the P710A, diode D1 detected the

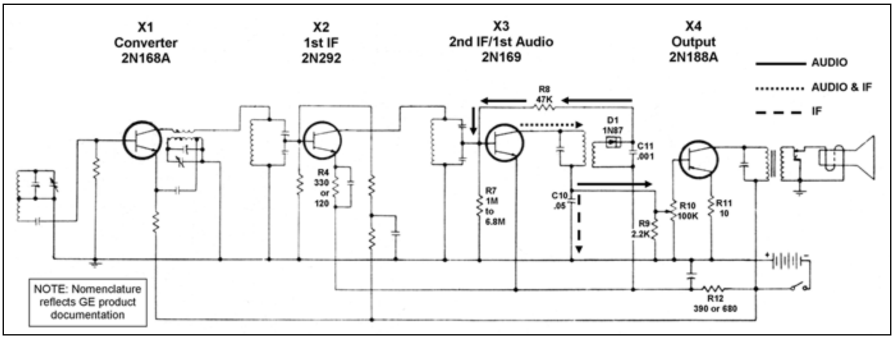


Fig.9A. P710A Schematic.

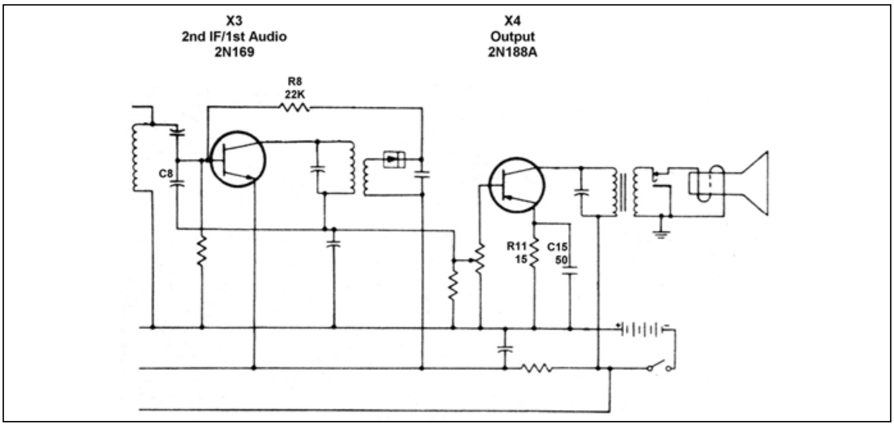


Fig.9B. P710B Output Stage Schematic.

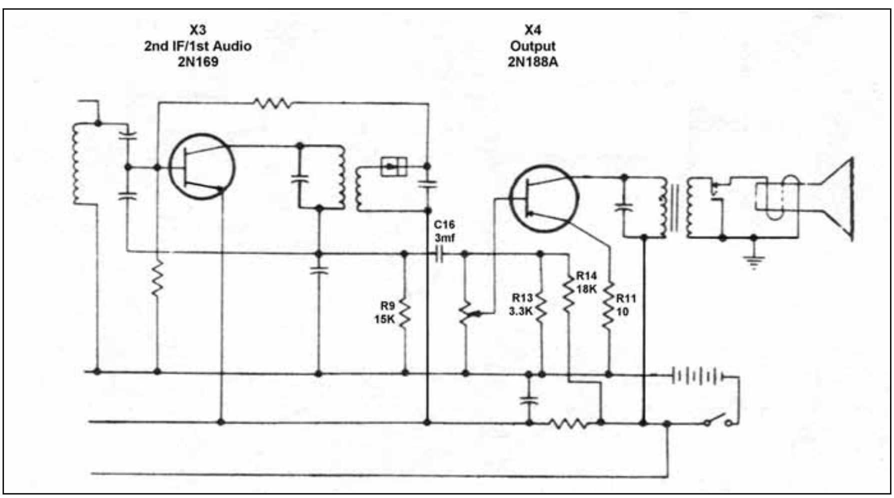


Fig.9C. P710C Output Stage Schematic.

audio signal which was then fed back through R8 to the base of X3 where it was amplified a second time as an audio signal. The combined audio and IF signal was taken from the collector of X3 and the IF portion bypassed to ground through C10. X3's collector current flowed through R9, developing an audio voltage in the process which was then applied to R10, the volume control.

A number of alternative transistors were allowed on the parts list and resistors R4, R9 and R12 were chosen as needed during production to optimize performance of the circuit. The reflex circuit is very sensitive to the gain of the combined RF/audio stage and R7 was chosen to have a value between 1.0 and 6.8 megohms depending upon the gain of the batch of transistors used for X3 to minimize distortion of the audio signal. As with the 675/676/677/678 model this resistor was conveniently located on the exposed side of the circuit board as shown in Figure 10.

Two changes were made in the P710B model to improve audio quality. Capacitor C8 was connected to a different point in the circuit, and in the output stage the emitter resistor, R11, was increased in value from 10 to 15 ohms and bypassed by capacitor C15, a 50 mfd electrolytic. However the improvement in audio from these changes was minimal.

The problem with the P710A and P710B designs was that the collector current of X3 flowed through the circuitry that fed the audio signal to X4 and thus the bias on X4 could not be adjusted independently of X3's collector current. The P710C model solved this problem by reconnecting R9, X3's collector resistor directly to ground and decreasing its value to 15K. The audio signal was then taken from the top of R9 and fed to the volume control

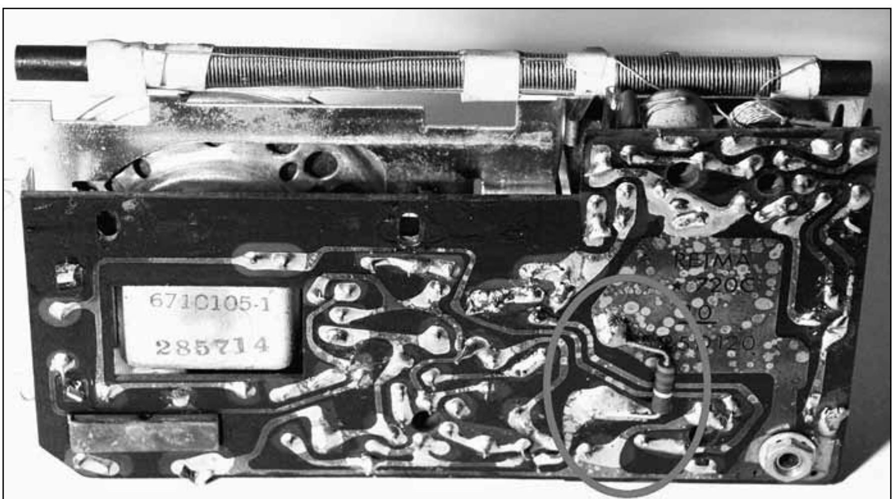


Fig.10. P710 Bias Adjustment Resistor.

through C16. In the output stage R13 and R14 were used to set the base bias current of X4. These changes resulted in X3's collector current being increased from 0.08mA to 0.12mA which provided added drive to X4. These bias changes on X4 increased its collector current from 8mA to 24mA—more than doubling the radio's audio output. The only downside of these changes was that the battery life of the P710C was about half of that of the A and B models.

While a battery life of 75–120 hours might have kept the public happy for the P710A/B radios, after all AA carbon-zinc cells were selling for $0.10–$0.13 in those days, the need to replace the batteries in the P710C twice that often was likely less appealing. GE offered the consumer an option—replace a set of dead batteries with either the usual carbon-zinc batteries, or with mercury batteries and get twice the battery life. Of course, to get twice the battery life you had to pay seven times as much for the batteries. And there was another drawback, the mercury cells looked like the AA cells they replaced, but their polarity was reversed with the "nipple" terminal on the mercury cells being negative, as opposed to positive on the carbon-zinc cells. So the P710/P711 models as well as a number of other GE radios of that era contained instructions inside the radio's housing to ensure that consumers installed the batteries properly.

Apparently some consumers never mastered the differences between carbon-zinc and mercury batteries however, for there are anecdotal stories from some of the service technicians of the time of these radios being brought in for service with the complaint, "I just put new batteries in and it still won't play!" The technician could open up the radio, check the battery polarity and find the batteries installed improperly. He could then make a quick trip to the back room to reinstall the batteries with the correct polarity, the radio would now work, and depending upon the technician the customer might or might not be charged for the "repair."

1957: Model P715 & P716 – But GE had a solution to the problem of battery life—their P715/P716 model [4a] offered the consumer the option of buying the radio alone (less batteries) for a price of $49.95. Or if they wished, they could pay $64.95 and buy the radio with a set of rechargeable nickel-cadmium (NiCd) batteries and a recharger case. This feature was also offered in several later models. GE's advertising for these models certainly caught your eyes with the statement "PLAYS UP TO 10,000 HOURS without changing batteries." But when you looked at the finer print you realized that "10,000 Hours" was not the playing time between battery recharges, but the total playing time on a set of NiCd cells before they reached the end of their useful life and had to be replaced!

The NiCd cells used in this model were the Eveready C450 (N46) for which the manufacturer specified recharging the batteries at a rate of

45 mA for 14 hours.[7] As shown in Figure 11 however, GE's initial circuit for the charger was simply a half-wave rectifier with no current limiting which maintained the batteries at a "float" voltage of about 2.8 volts for as long as the radio was plugged into the charger. Later in production the circuit was modified by the addition of a series resistor which provided a nearly constant charging current of about 40 mA which more closely matched the manufacturer's recommendation and reduced the likelihood of overcharging the batteries.

1959: Model P785, P786 & P787 – GE's first transistor radio used only GE transistors (this was before the day of multiple sources for commonly used semiconductors). However in later models, because of cost and availability issues, GE turned to using transistors from different suppliers. Philco, Raytheon, RCA, CBS and Sylvania were commonly-used suppliers, and it was not uncommon to see 4 or 5 different transistors listed as alternates on the schematic along with notes concerning minor component changes depending upon which transistor was used.

Occasionally however none of the alternates could be obtained in sufficient quantities and at the right price so in the model P785/P786/P787 [4a] GE incorporated a "phantom wiring diagram" in the class B push-pull output stage of a number of their transistor radios, as shown in Figure 12, that would allow the substitution of PNP devices for NPN devices, and vice versa, during the manufacturing process. By changing two jumpers on the circuit board this approach reversed the polarity of the voltage applied to the transistors, and reversed the position of the two resistors forming the bias network. Of course, both transistors in the output stage did have to be of the same type and be a matched pair, and any technician servicing these models had to deal with the added complexity of the optional circuitry.

1959: Model P800 – GE's vacuum tube radios of this era used a permanent magnet speaker with a voice coil driving the paper cone. Their early

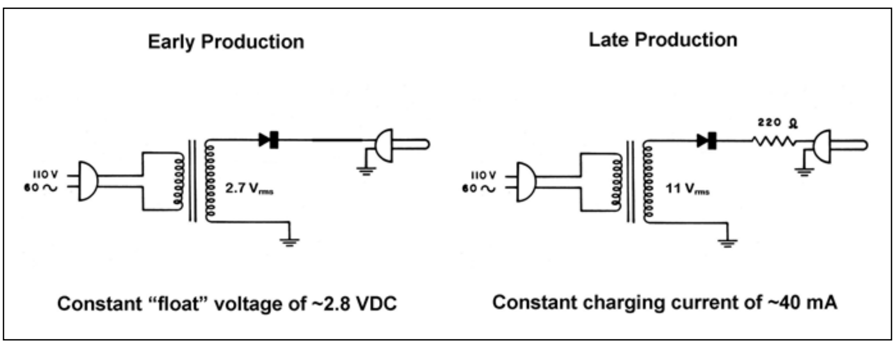


Fig.11. P715 & P716 Charging Circuit.

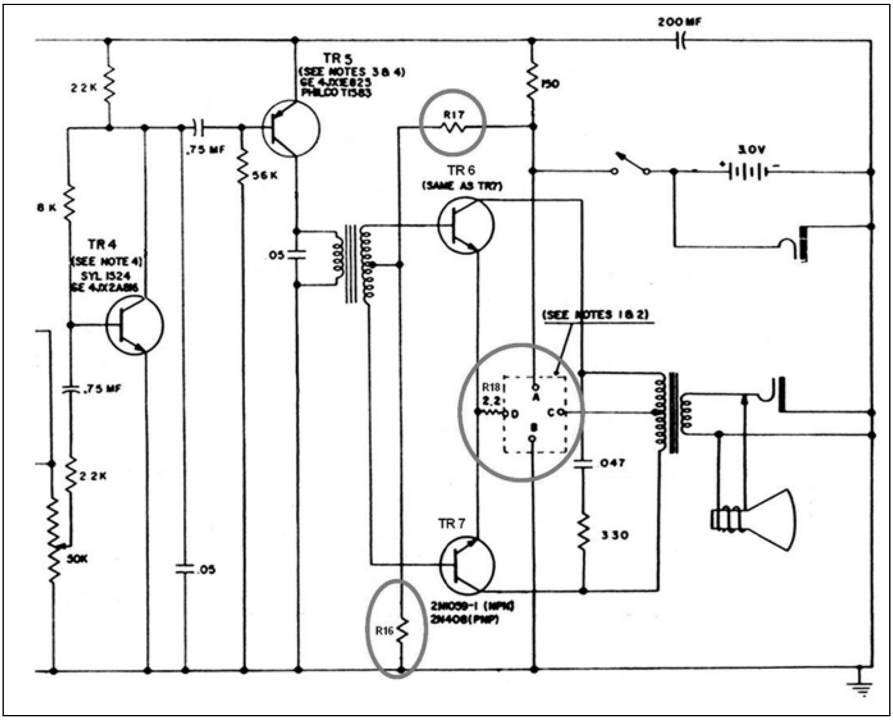


Fig.12.P785, 786 & 787 Output Stage.

transistor portables used the same technology—just reduced in size as much as possible, from the 4" or 5" speakers used in their vacuum tube radios to the 2.75" speakers in their transistor portables. But even with the smaller speaker, the early transistor radios still required a matching transformer to reduce the desired load on the output stage from the hundreds of ohms needed by the transistors to the 4–8 ohms commonly provided by the speakers in the early radios. The weight and size of the speaker and output transformer placed limits on how small and light the radio could be made. And the miniature output transformers had efficiencies of the order of 70% [2] which further reduced the audio output of the radio.

A popular 1974 song had the title of "Everything Old Is New Again" and the same was true of the speakers that GE began using in their later transistor portables – an improved version of a speaker design popular in the 1920s. Beginning with the P800 [4a], GE replaced voice coil speakers in its smaller portables with armature speakers (sometimes also referring to them as "dynamic" or "magnetic" speakers in their service literature). In an armature speaker the voice coil was replaced with a magnetic armature, polarized with a permanent magnet, and surrounded by an electromagnet. The armature was mechanically coupled to the voice coil as shown in Figure 13. The high impedance electromagnet winding replaced the primary of the traditional output stage matching transformer and induced a varying magnetic field in the armature which caused it to vibrate in step with the audio signal. A much smaller and more modern version of this design, as shown in Figure 14, allowed GE to eliminate the output transformer and also resulted in a smaller, lighter and thinner radio as well as a less expensive design. But the armature speaker did have a drawback that eventually ended its use as we'll see shortly.

1960: Models P850, P851 & P852 – By further reducing the size of the of the armature speaker to 2", using a single 4V mercury battery, and incorporating smaller variable capacitors, IF transformers and volume controls that had been developed during the later 1950s, GE was able to introduce its first truly shirt pocket radio shown in Figures 15 and 16 [4a; 4b; and 4c]. Weighing in at 10

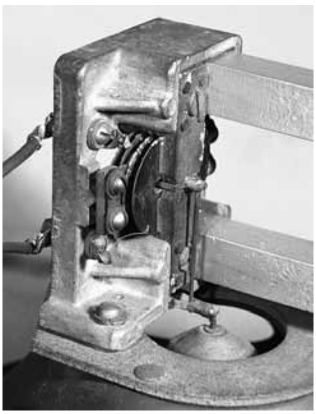


Fig.13A. Closeup of 1920s era "Peerless Reproducer" armature mechanism.

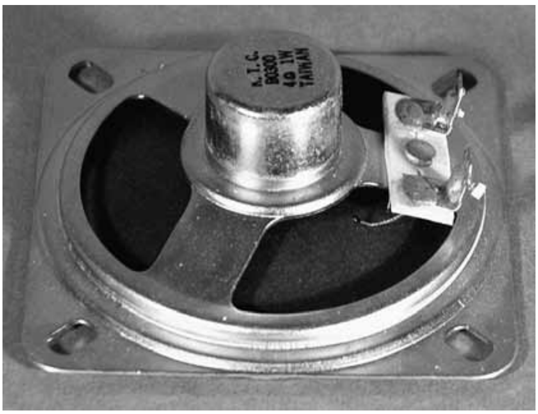


Fig.13B. Conventional 3" voice coil speaker.

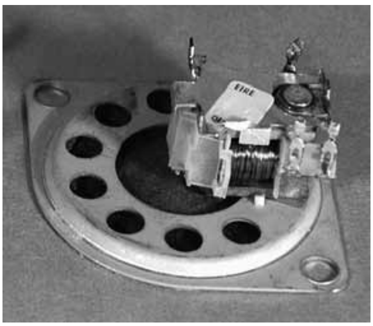


Fig.14A. Modern 2" armature speaker.

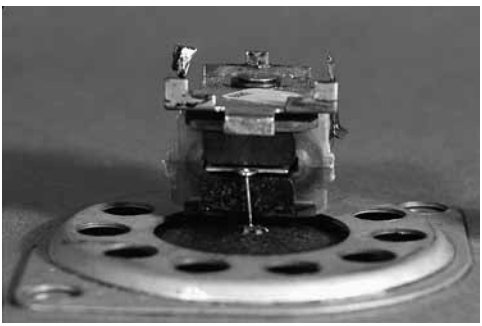


Fig.14B. Closeup of modern armature mechanism.

Fig.15. P850 Advertisement.

Fig.16. P851 Advertisement.

ounces, this radio had a solid "feel" in the hand, good audio quality, considering the small size of the radio, and a vernier tuning mechanism which made fine-tuning a station easy. Judging by the frequency with which this model appears on eBay and in fleamarkets today it was a popular design and sold in large numbers.

Two Non-Portable Models

While we've been discussing portable transistor radios so far, we should note that GE introduced transistors in radios other than their portables. During the 1950s GE also introduced transistors into a table radio and a clock radio as shown in Figures 17A (right) and 17B (overleaf). Several manufacturers were offering "travel pairs" during this time which paired a transistor portable radio with a separate conventional wind-up alarm clock in a single carrying case.

Fig.17A. GE Models T145 & T146 Transistorized Table Radios.

Fig.17B. GE Model CT455 Transistorized Clock Radio.

But GE integrated the two in their model CT455 clock radio [4a] which incorporated a 6-transistor circuit and a clock, having a battery powered autowind mechanism, which could turn the radio on at the selected alarm time. GE's T145/T146 table radio[4a] used a 7-transistor circuit powered by 3 "C" cells. While it offered battery operation and "instant on" features of a transistor radio its 200 mW of audio resulted in significantly lower volume than the 1+ W of audio offered by vacuum tube table radios of the time and because of the cost of transistors, it was at a cost disadvantage.

As GE moved from the 1950s into the 1960s it was able to offer transistorized portable radios in several size ranges that offered performance equal to or better than vacuum tube portables of that era and GE's last vacuum tube portable radio was the model P735/P736 [4a] produced in 1958.

It took a little longer for the transistor to supplement vacuum tubes in GE's table radios but the handwriting was on the wall and GE's last vacuum tube AM clock radio was the model C545/C546/C547 [4c] of 1965. In 1966 GE produced their last vacuum tube AM table radio in the model 5125/5129 [4c; and 4d] although vacuum tubes continued to be used for several years in higher end AM/FM radios and audio equipment.

What is remarkable is how in just 3 years a completely new technology, introduced in the mid-1950s, had completely replaced the vacuum tube technology that had reigned supreme in GE's portable radios for 4 decades. But as the company moved into the '60s and '70s it faced increasing competition from lower-cost foreign suppliers as well as the growing popularity of FM with its better sound quality. Let's see how those challenges shaped GE's product line.

The P755/P80x Series

In 1958 GE had introduced the P755 model [4a] which can at best be described as a portable that performed adequately, but not excitingly. It was a mid-sized portable and the housing was basically a rectangular box that, as with the Ford Model T, came in any color you wanted—as long as it was black. Its single-ended output stage produced about 75 mW of audio which drove the 3.5" voice coil speaker to produce audio of reasonable quality. Typically a design such as this would be produced for one year, two at the most, and then be replaced by a new model with updated styling and possibly circuit improvements. But through a number of changes GE was able to extend the life of this basic model through 1964—a span of 7 years—how was this accomplished?

In 1959 the P755 was reintroduced as the P805A/P806A [4a and 4b] which was basically the P755 but with the choice of a black or white housing. The following year in 1960 it was again reintroduced as the P807A/P808A/P809A which added a green housing to the lineup. At the same time the plain black speaker grille was replaced with a grille of the same color as the housing but with swirls of color. By keeping the same basic radio design, except for cabinet color, GE was able to take advantage of the cost reductions inherent in volume production and the model P807 was offered at the then-low price of $16.95 as shown in Figure 18.

Fig.18. GE's Low Priced (for the time) Portables.

Also in 1960 GE introduced the B & C models to replace the earlier A models with the new models replacing the 3.5" voice coil speaker with a 3.5" armature speaker. The lower weight and cost of the armature speaker, coupled with the elimination of the output transformer reduced weight from the 32 oz. of the P755 to the 26 oz. of the "B" and "C" models.

In 1964 a further change was made [4c] when discrete components mounted on a PWB were replaced with three modules (converter, IF and audio) mounted on a much simpler interconnect board. These modules were used in other GE portables of the time, resulting in further cost reductions from high volume production. In addition to the modular construction, use of newer transistors in the audio output stage boosted the audio from about 75 mW to over 100 mW in the later models. The evolution of the design from the P806A to the P807H is shown in Figure 19.

But all things must eventually come to an end, and the 1964 models were the last in the series. What ended the series? The features that initially made it popular—a low cost AM receiver with relatively good audio—were no longer sufficient to induce the public to buy the product in large quantities. FM broadcasting was beginning to overtake AM in popularity, GE introduced its first AM/FM receiver in 1961 and by the mid '60s half of its models were multiband. So, why not add FM to the P80x series? The problem was that the armature speaker that reduced the weight

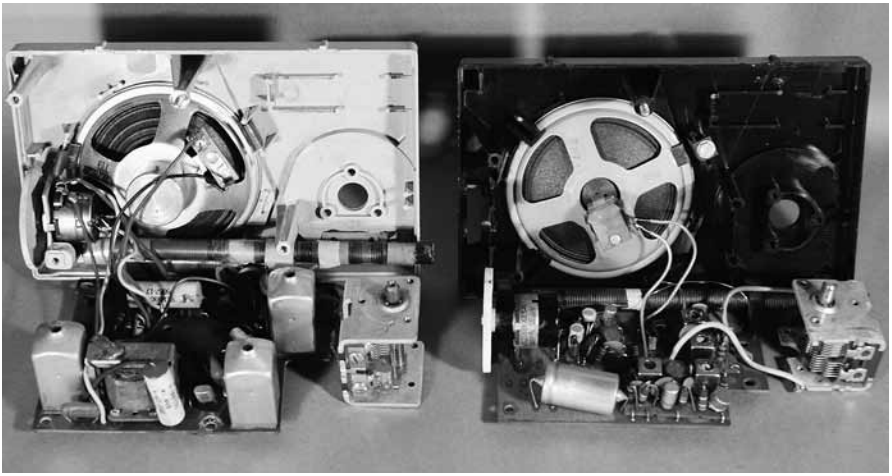


Fig.19. P80x Radio Design Evolution (L to R)

Model	P806A	P807H
Prod. Year	1959	1964
Band	AM (0.54-1.62MHz.)	AM (0.54-1.63MHz.)
Speaker	3.5" voice coil	3.5" armature
Volume Control	Housing mounted	PWB mounted
IF Transformers	Medium size	Miniaturized
Wiring	PWB and Point-to-point	3 PWB modules, motherboard mounted, some Point-to-point
Output Xfmr	Full sized	None
Weight	32 oz. (with battery)	25 oz. (with battery)

and cost of that series of radios had a problem—poor audio quality.

Figure 20 taken from [8] shows a simplified equivalent circuit for a loudspeaker. Re and Le are the electrical resistance and inductance of the voice coil, or in the case of the armature speaker, the armature magnetizing coil. Lm and Cm are the electrical equivalents of the mass, and compliance of the cone and its suspension, and Rm is the electrical equivalent of the acoustical load on the loudspeaker's cone presented by the air in which it vibrates. Appendix A discusses this equivalent circuit and the measurement of its properties in greater detail.

In a voice coil speaker, Re and Le are relatively small and the speaker will typically present an impedance of 4–8 ohms at 400Hz. But with an armature speaker Re and Le are much larger and the impedance of this type of speaker typically presents an impedance of 500-600 ohms at 1 kHz. Further, the larger value of Le will result in a speaker impedance curve that rises more rapidly with frequency than for a voice coil speaker. Measured impedance curves of both the voice coil speaker used in the P807A and the armature speaker used in the P807C are shown in Figure 21 which illustrates how the different designs produce very different curves of impedance versus frequency. Since

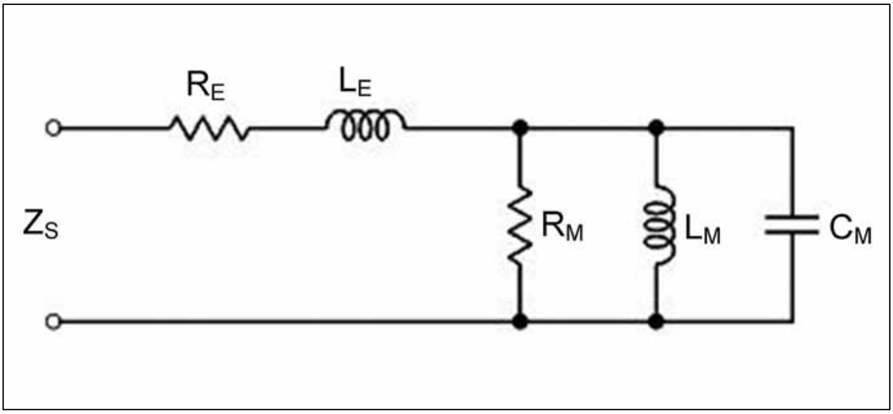


Fig.20. Speaker Equivalent Circuit.

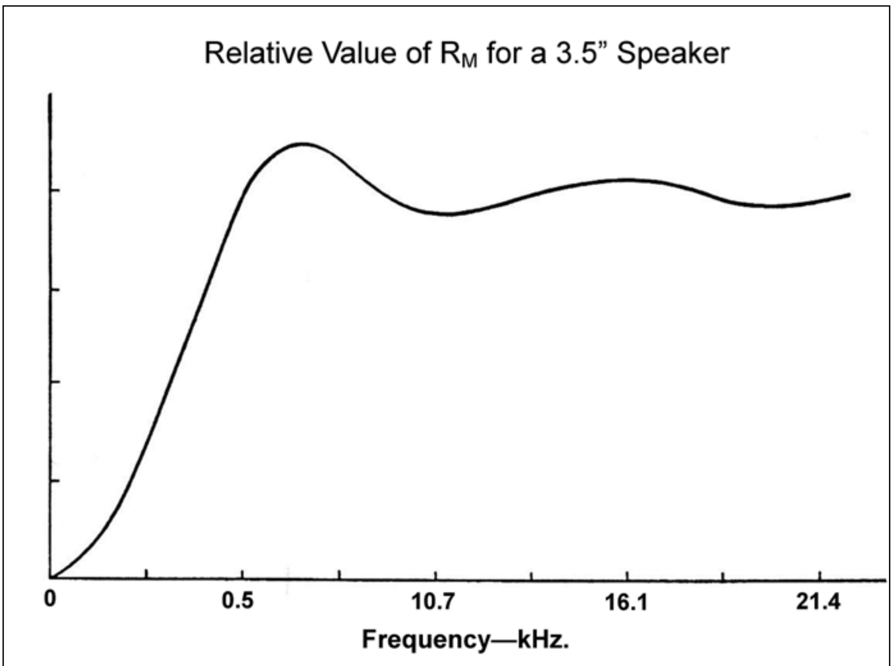


Fig.21. Speaker Impedance.

these two types of speakers have greatly different impedances, the curves are normalized to each speaker's impedance at 1 kHz.

Why care how a speaker's impedance varies? A radio's output stage is designed to deliver a rated amount of power to a particular load impedance. To the extent that the actual load impedance is much higher or lower than the design value, generally less power will be delivered to the load. Less power equates to less audio output. Suppose that a particular radio's output stage will deliver an acceptable amount of power into a load that varies +/- 200% about the design value. Then the voice coil speaker in the P807A meets this requirement up to about 2,400 Hz, while the armature speaker in the P807C meets this only over the range from about 750 Hz to about 1,250 Hz. Of course this is a simplified analysis and many other factors such as speaker efficiency, output stage characteristics, etc. come into play. But clearly the armature speaker has a much narrower frequency response than does the voice coil speaker—and that was its downfall.

Foreign Competition

While consumers were initially willing to purchase shirt pocket-sized portable radios and accept the tradeoff of lower audio against small size and weight, as the 1960s evolved they were no longer willing to pay the prices for these radios that would allow GE to make what they felt was a reasonable profit. In the early 1960s the company continued to sell inexpensive shirt pocket radios produced domestically, typically for about $10 with some as low as $6, through 1965. But to remain competitive domestic production was moved offshore in the mid-'60s, first to Hong Kong, then to Japan, and eventually to Malaysia. However this production move only postponed the inevitable and by the end of the 1960s, GE's portable radio product line had shifted almost exclusively to multi-band and larger and more expensive radios.

The company was able to extend the life of the AM-only portable radio product line through the 1970s by using innovative packaging designs and selling the "novelty" radios as higher priced, lower volume products targeted at specific consumers. One of the more interesting models was the P3460, "The General", which was based upon the locomotive of that name from the Civil War era that featured prominently in the movie "The Great Locomotive Chase."

As mentioned earlier, the popularity of FM broadcasting spelled the end of the P755/P80x series of radios. And the intense price competition in AM-only pocket radios led GE to largely abandon this type of radio with the exception of the novelty radios mentioned earlier.

The company's focus going into the 1970s lay in the medium-sized multi-band portable radios typified by thP965/P968/P975 [4c and 4d] in Figure 22, and the full-sized multi-band high quality radios typified by the model P990 [4c] in Figure 23.

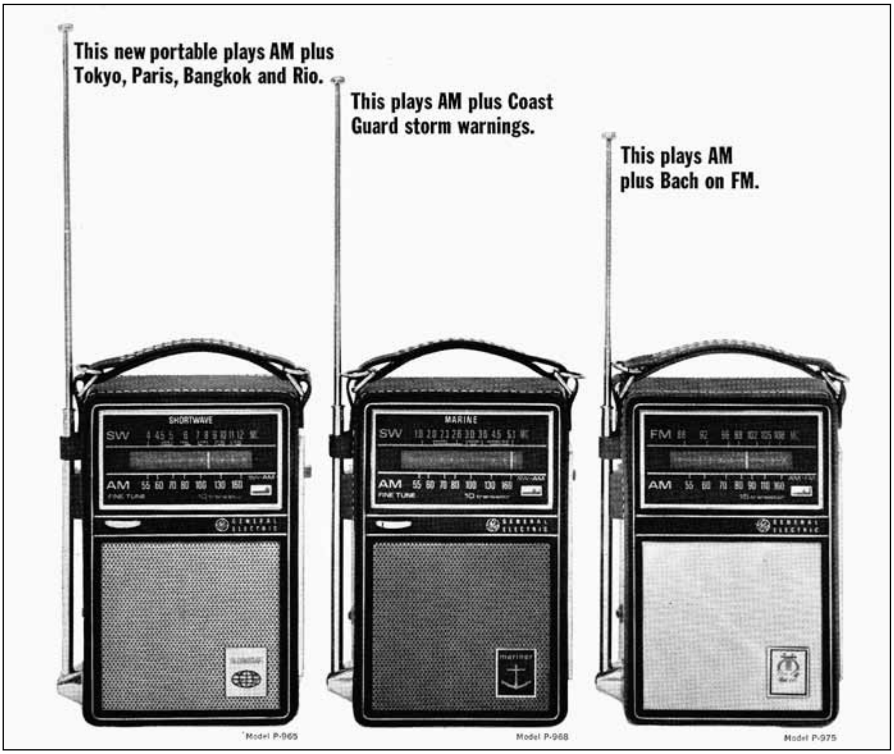


Fig.22. GE's Early Multi-Band Portable Radios (L to R)

Model	P965	P968	P975
Prod. Year	1964	1964	1964
Bands	AM (0.54-1.62MHz.) SW (4-12MHz.)	AM (0.54-1.62MHz.) SW (1.8-5.1MHz.)	AM (0.54-1.63MHz.) FM (88-108MHz.)
IF	0.455MHz.	0.455MHz.	0.455 & 10.7MHz.
# Transistors	10	10	15
Price	~$40	~$40	~$50

Fig.23. GE Full-Size, Multi-Band Radio

Model	P990
Prod. Year	1967
Bands	LW (0.17-0.40MHz.) AM (0.54-1.62MHz.) SW1 (1.8-5.1MHz.) SW2 (6-18MHz.) FM (88-108MHz.)
IF	0.455 & 10.7MHz.
# Transistors	17
Speaker	4"
Price	~$125

Summary

Thus, in the space of 15 years, the company had:

- Mastered the transition from vacuum tubes to transistors in portable radios.
- Developed and then abandoned the small, lightweight armature loudspeaker.
- Perfected and then largely phased out the AM-only, shirt pocket radio it struggled to develop in the 1950s.
- Entered the decade of the 1970s with profitable lines of multi-band, high quality radios that it would continue to produce for 20 years.

However a number of challenges would still face the company, and the industry in general, in future years as consumers were moving away from AM/FM radios as personal entertainment devices with the Walkman, iPod and eventually Wi-Fi devices and the iPhone taking over a large sector of this market.

But how the company dealt with those is another story.

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1. "The Editors Report on ELECTRONICS PARK", pages 1–24, Electronics Magazine, October 1948.
2. "General Electric Transistor Manual – fifth edition", pages 67–81, 1960, Semiconductor Products Department, General Electric Company, Charles Building, Liverpool, NY.
3. GE's "Service Manuals" and "Service Data" provide more detailed information on maintaining and servicing their radios than do the "Radio Service Guides" listed below. In addition to schematics and parts lists found in the Service Guides, these publications describe adjustments in greater detail, provide additional photos and location diagrams, and identify special tools and test equipment. These documents were issued individually for each model.
   3a – "Preliminary Service Data, Models 675 and 676", October 1955, General Electric Product Service – Radio and Television Department, Electronics Park, Syracuse, NY.
   3b – "Service Manual for Pocket-Size Portable Receivers, Models 675, 676, 677 and 678", June 1956, General Electric Product Service – Radio department, 867 Broad Street, Utica, NY.
4. GE's "Radio Service Guides" typically include schematics and parts lists for each model. Pages at the beginning of each guide included photos of each model to assist in identifying the model numbers. These Guides are spiral-bound volumes covering a range of models. They were widely distributed and show up frequently on eBay and in flea 8markets. In addition some have now been scanned and are offered as PDF files on CDs.
   4a – "GE Radio Service Guide, Volume III, 1946 to 1961", General Electric Product Service – Radio Receiver Department, 1001 Broad Street, Utica, NY.
   4b – "GE Radio Service Guide, Volume IV, 1961 to 1963", General Electric Product Service – Radio Receiver Department, 1001 Broad Street, Utica, NY.
   4c – "GE Radio Service Guide, Volume V, 1963 to 1965", General Electric Product

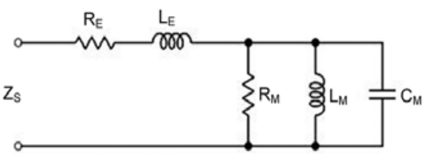
Service – Radio Receiver Department, 1001 Broad Street, Utica, NY.
4d – "GE Radio Service Guide, Volume VI, 1965 to 1967", General Electric Product Service – Radio Receiver Department, 1001 Broad Street, Utica, NY.
5. "Eveready Battery Engineering Bulletin No. 9", pages 4–9, 1960, Union Carbide Consumer Products Company, 270 Park Avenue, New York 17, N. Y.
6. Personal communication with Mr. Louis Agresti-W2OPF, designer of automatic test equipment for GE's early transistor production lines in Syracuse, NY.
7. "Eveready Battery Applications and Engineering Data", pages 652–662, 1968, Union Carbide Corporation, Consumer Products Division, 270 Park Avenue, New York, N.Y. 10017.
8. "Fundamentals of Acoustics", page 253, 1950, Lawrence Kinsler and Austin Frey, John Wiley & Sons, Inc.

Appendix A

Loudspeaker Equivalent Circuit and Measurements

Equivalent Circuit Values

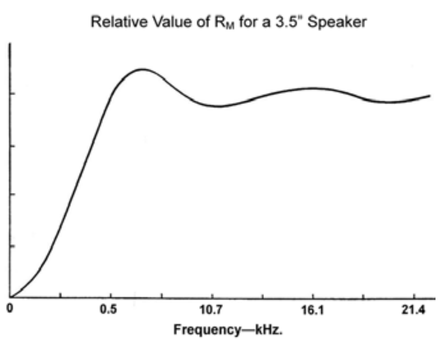
Earlier in this paper the following equivalent circuit for a loudspeaker was presented (Figure 20):



There are a number of equivalent circuits that may be used to represent a loudspeaker. This circuit is a little more detailed than some, and a lot less detailed than others. To a large degree, the complexity of the equivalent circuit that you use depends upon what use you want to make of it. For a simple discussion of the impedance-versus-frequency characteristics of a loudspeaker this circuit will suffice. But it does have limitations.

One limitation is that the values of the circuit components. R_E, L_E, L_M and C_M can, for our purposes, be considered relatively constant. R_M which represents the radiation resistance, or the acoustic load on the loudspeaker imposed by the air is a function of frequency however, and Reference 8, pages 177-183 discusses this in great detail.

Working through the calculations in Reference 8 for a 3.5" loudspeaker in air, we find that R_M varies as a function of frequency as follows (Figure 21):



At low frequencies, R_M is negligible, then rising and reaching a fairly stable value at about 500 Hz. and higher.

What this means for determining

the loudspeaker equivalent circuit values is that at DC R_M drops to zero, essentially shorting out L_M and C_M. Likewise, at DC the impedance of L_E is zero and thus when Z_S is measured, the value is that of R_E. Unfortunately determining the other equivalent circuit values is much more difficult both because the equivalent circuit shown above does not take into account effects such as other modes of vibration and the fact that some other values are also frequency dependent.

Measuring Speaker Impedance

Because of the difficulty in easily and accurately modeling a speaker, its impedance is generally measured, as opposed to calculating it from an equivalent circuit.

Here again, there are complications because the speaker impedance, Z_S, is a complex number – that is it has both a resistive and a reactive component, or:

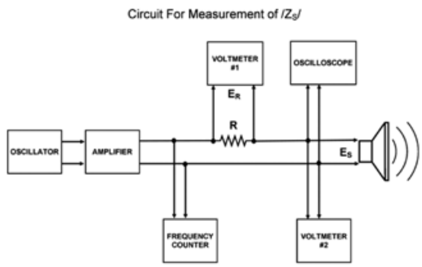
$$Z_S = R_S + jX_S$$

with R_S being the resistive component and X_S being the reactive component. Equipment that can measure both the resistive and reactive components of an impedance is generally not found in the usual hobbyist's workshop.

But for quick and simple investigations of loudspeaker impedance and the effects introduced by the radio's housing, A simpler measurement of the magnitude of Z_S where:

$$/Z_S/ = \sqrt{(R_S^2 + X_S^2)}$$

Can be made using the following circuit (Figure 24), which in fact is what was done to obtain the plot of Figure 21:



R should be a good quality non-inductive resistor rated at several watts. The value should be chosen so that it is approximately equal to $/Z_S/$—the goal being to keep E_R and E_S roughly equal although this is not critical. It is a good idea to use a battery-operated voltmeter for #1 so as not to introduce grounding problems. And the purpose of the oscilloscope is to monitor the waveform of E_S, the voltage across the loudspeaker. Especially at low frequencies where the loudspeaker audio output is low and cone excursions are large, it is easy to overdrive the loudspeaker and have the cone motion become nonlinear or even to have the cone bottom out the suspension—either event will introduce harmonic frequencies into E_S and the calculated value of $/Z_S/$ will be in error. And finally, the loudspeaker itself should be placed face up on an isolating pad and without any reflecting surfaces within several feet of the front of the loudspeaker.

Then. at each frequency for which E_R and E_S are measured the magnitude of Z_S may be calculated from:

$$/Z_S/ = R * (E_S/E_R)$$

While this approach requires the manual measurement of two voltages and a simple calculation at each frequency of interest, and allows only the measurement of the magnitude of the loudspeaker's impedance and not the real and imaginary components of the impedance, it is simple and accurate enough for the hobbyist who wishes to experiment with various loudspeakers and study the effects of the housing the loudspeaker is mounted in.

Acknowledgements

I am grateful to the staff and volunteers of the AWA's Electronic Communication Museum for the countless hours they allowed me to spend examining hardware and documents in "The Annex" while researching this article.

And to Chris Hunter, the Archivist at the Museum of Innovation and Science in Schenectady, NY, which is the repository of General Electric's "Hall of History" files, for allowing me to spend many hours going through those files and extracting information for this and other projects.

And to the Liverpool Public Library whose "Living Legends" series of local video histories allowed me to compile the "Electronics Park" video history which describes how General Electric converted farmland outside of Syracuse, NY into Electronics Park—the headquarters of the company's consumer electronics business for many years (www.DanMoore.com/ElectronicsPark).

And finally to the former employees of General Electric whose accounts of their work in the offices, laboratories and on the production lines as they struggled to bring the new technology to market provided much background information for this article.

About the Author

Stephen Auyer, N2TKX, holds a BS in Physics from the University of Cincinnati and an MBA from Syracuse University. In 2001 he retired after a 34-year career in General Electric's Aerospace Operations, and their successor organization—Lockheed Martin. During that time he held several engineering and management positions and was involved with: underwater acoustic devices and sonar systems; ballistic missile inertial guidance systems, and air defense radars.

The majority of his career was spent in General Electric's operations in Syracuse, New York where he was able to view firsthand the development and application of transistors and other solid state devices, as well as the design and production of radios and television sets. During his career he was fortunate to be able to visit numerous locations where General Electric produced consumer electronics, including: Utica and Schenectady, NY; Bridgeport, CT; Fort Wayne, IN; Cincinnati, OH and Louisville, KY. He has long been a collector of General Electric radios and television sets and has a collection that spans 8 decades—both of the products themselves and the company documentation that supports them.

A former member of the Acoustical Society of America and the American Institute of Physics, his interests since retiring have centered more on amateur radio and the history of General Electric's commercial and military electronics products. He is a member of the American Radio Relay League, the Antique Wireless Association, and the Tube Collectors Association. He has published articles in the magazines, journals and newsletters of those organizations. He currently edits and publishes monthly newsletters for two amateur radio clubs and is the former editor and publisher for the Amateur Radio News Service.

Stephen Auyer with granddaughter Lucy Elizabeth Auyer on his 70th birthday

DOCUMENTING DISCOVERY

The Centennials of Two Leading Journals

Abstract

The years 2012 and 2013 marked the centennials of two esteemed publications that document the important discoveries in radio and electronic communications. The *Proceedings of the Institute of Electrical and Electronics Engineers* and the *Proceedings of the Radio Club of America* both trace their origins to the earliest days of wireless telegraphy and radio. One marks the beginning of the world's largest professional society, and the other marks the beginning of a less formal, but highly prestigious club, or forum, where many of the preeminent leaders of the new technology gather. Both organizations counted among their members many of the major inventors, academics and developers of wireless technologies. Both publications shared numerous historically significant articles that introduced the ideas and techniques that proved essential for the new electronic communications technology to expand and prosper. This article outlines the contributions of these two historic publications to encourage use of their materials by AWA members and other researchers in these fields.[1]

Introduction

Two of the preeminent publications that brought scientists, inventors and developers news about discoveries involving radio and wireless communications each celebrated their centennials in 2012 and 2013. They offer an interesting juxtaposition between a journal produced by an organization seeking to be a preeminent professional society, versus a journal produced by a club seeking to break down barriers by providing a forum for the top leaders in the field, regardless of their backgrounds.

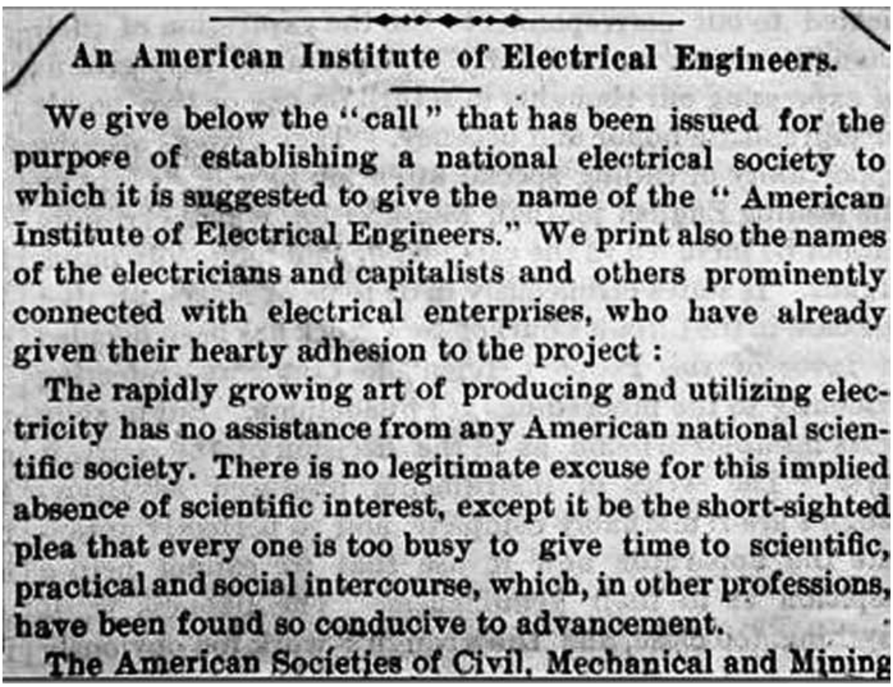
Part I of this article explains the early history of the Institute of Electrical and Electronics Engineers (IEEE) and its publication, the *Proceedings of the IEEE*; identifying some of the most important historical articles relating to radio topics. Part II describes the history of the Radio Club of America (RCA) and its publication, the *Proceedings of the RCA*; providing a survey of subjects covered by its journal. Part III comments on the current state of the two organizations and the legacies of their premier publications.[2] Part III also offers an introduction to the resources available for research through IEEE and RCA.

PART I — THE PROCEEDINGS OF THE IEEE

The IEEE is the largest professional society in the world. It is dedicated to the entire electrical and electronics engineering profession. Within that overarching umbrella sit those members dedicated to electronic communications. 2012 marked the centennial of the *Proceedings of the IEEE*, the IEEE's premier journal. The IEEE celebrated that centennial by selecting and highlighting "Classic Papers" that were published during the past 100 years. Many of the Classic Papers have their origins in radio and wireless history. The Classic Papers series concluded in December 2012.

Origins

The *Proceedings of the IEEE* evolved over a long and rich history that can be traced back to 1909, when it was first known as the *Proceedings of The Wireless Institute* (TWI). TWI was the first truly professional organization dedicated to radiotelegraph communications. Robert H. Marriott, then the Assistant Scientific Manager of the United Wireless Telegraph Company, formed TWI in 1909 as a professional society focused on radio engineering, and became its first President. TWI, located in New York, was modeled after the American Institute of Electrical



An American Institute of Electrical Engineers.

We give below the "call" that has been issued for the purpose of establishing a national electrical society to which it is suggested to give the name of the "American Institute of Electrical Engineers." We print also the names of the electricians and capitalists and others prominently connected with electrical enterprises, who have already given their hearty adhesion to the project :

The rapidly growing art of producing and utilizing electricity has no assistance from any American national scientific society. There is no legitimate excuse for this implied absence of scientific interest, except it be the short-sighted plea that every one is too busy to give time to scientific, practical and social intercourse, which, in other professions, have been found so conducive to advancement.

The American Societies of Civil, Mechanical and Mining

The "Call" to Organize the AIEE from Electrical World April 5, 1884. (Courtesy IEEE Global History Network, Image 5310.)

Engineers (AIEE). But, unlike the AIEE, TWI also promoted educational goals by developing its own publication for distribution to its members.

The AIEE first organized twenty-five years earlier, in 1884. In April, Nathan S. Keith, along with Thomas Edison, Elihu Thompson, Edwin Houston, Edward Weston and twenty other prominent leaders in the American electrical sciences, issued three published "calls" to create a national organization representing the electrical and telegraph industries. They ostensibly wanted the Americans to participate in the upcoming Philadelphia International Electrical Exposition on an equal footing with their international peers. That September, the newly formed AIEE held its initial meetings at the Franklin Institute in conjunction with the Exposition. Later that fall, six papers were presented, and then published as the first issue of the *Transactions of the AIEE*. Going forward, the AIEE would continue to issue reprints of papers presented at its activities as *Transactions* that were released under the auspices of its various technical subcommittees.

In the ensuing years, AIEE hosted meetings covering a wide array of electrical technologies. Although early topics included telegraph and telephone communications, the challenges of electric power generation and the design of electric motors soon dominated the interests of the AIEE. The standardization of electrical units, definitions and nomenclature also were top priorities. Edison's legendary battle with Nikola Tesla and George Westinghouse regarding alternating versus direct current technologies grabbed further headlines, focusing attention on the research and development of power generation and electrical distribution.

Unfortunately, communications technology found itself relegated to a secondary concern of the society. Between 1884 and 1912, the AIEE published 750 papers, with only 7 dedicated to radio related topics. In the words of John V.L. Hogan, "The radio men… were not satisfied with the idea of perhaps one or two papers per year, sandwiched in between meetings devoted to what the Germans call 'heavy-current' electrical engineering."[3] They needed a place to communicate and share their writings.

Thus, the *Proceedings of TWI* became the first dedicated professional journal in the field of wireless engineering. In total, six issues of the *Proceedings* were published in 1909 under the direction of Greenleaf W. Pickard and Alfred N. Goldsmith who had become the journal's editors. The first two papers were authored by Marriott and Dr. Michael I. Pupin:

- Marriott provided the first article; outlining the history of TWI, the reasons for its existence, and providing a plan for submitting future papers and publication of the *Proceedings*.
- Pupin's paper "A Discussion on Experimental Tests of the Radiation Law for Radio Oscillators" provided the first topical content.

Pupin's paper was selected from a number of unpublished papers previously presented at TWI. Pupin, the legendary father of electrical science education at Columbia University, later became the fifth President of the Institute of Radio Engineers.

John Stone Stone had established Boston's Society of Wireless Telegraph Engineers (SWTE) two years earlier, in 1907. SWTE held meetings but did not publish. In the ensuing years, changes in sponsor company affiliations and wireless company relocations between Boston and New York affected internal loyalties. By 1910, both TWI and SWTE struggled to maintain memberships.

Stone and Marriott found a solution by merging New York's TWI with Boston's SWTE to form the Institute of Radio Engineers (IRE). On May 13, 1912, the members of TWI and SWTE gathered at Columbia University in New York City and approved the constitution of the new organization. The IRE now possessed a distinctive new focus. Although it attracted disaffected AIEE members with interests in wireless and radio technology, many of IRE's members had, in fact, never been part of AIEE. The IRE therefore represented the emergence of an entirely new engineering field. Ironically, AIEE had finally authorized creation of a Radio Transmission Committee the same month, but it was too little, too late.

Both Pickard and Goldsmith wanted the IRE to continue TWI's journal and renamed the publication as the *Proceedings of the IRE*. Volume 1 was published in January 1913. Goldsmith continued as editor of the IRE's *Proceedings*. Despite the fact that the first publication was in 1913, IEEE recognized the official centennial of the *Proceedings of the IEEE* as May 2012, in honor of the founding and election of IRE's officers in May 1912.

The Institute of Radio Engineers

IRE Logo (Courtesy of IEEE).

Alfred N. Goldsmith, First and Longest Editor of Proceedings of the IRE. (Courtesy IEEE History Center).

TABLE 1.
TIMELINE OF KEY IEEE DATES

Entity	***Journal***	***Event***
1884		American Inst. Electrical Engineers (AIEE) Established
	1884	*Transactions of the AIEE* Published
1907		Society of Wireless Telegraph Engineers (SWTE) Formed
1909		The Wireless Institute (TWI) Formed
1909		Jr. Aero Club Formed (renamed as RCA in 1911)
	1909	*Proceedings of TWI* Published
1911		Radio Club of America renamed
1911		TWI & SWTE Merge Forming Inst. of Radio Engineers (IRE)
1912		IRE Formally Organized
	1912	RCA Publishes First *Amateur Radio Call Book*
	1913	*Proceedings of the IRE* Published
1914		Amateur Radio Relay League (ARRL) Formed
	1915	First Issue of *QST* (ARRL) Published
1950		AIEE Forms Communications Division
1952		IRE Forms Professional Group Communication Systems (PGCS)
1957		IRE Membership Exceeds AIEE
	1959	50th Anniversary *Golden Yearbook of Proceedings of RCA*
	1962	50th Anniversary Edition of *Proceedings of IRE*
	1962	*IRE Transactions on Communications Systems* Published; Renamed *Transactions on Communications Technology* 1963
1963		AIEE and IRE Merge Forming Institute of Electrical and Electronics Engineers (IEEE) (approx. 150,000 total members)
1964		AIEE Communications Div. Merges With IRE PGCS To Form IEEE Group on Communication Technology (ComTech)
	1964	*IEEE Spectrum* Published
1972		IEEE Communications Society (ComSoc) Formed
	1972	*Comsoc Transactions on Communications* Published
1984		Centennial of AIEE
2009		Centennial of RCA
	2011-12	Centennial Year of *Proceedings of IEEE* (Classic Papers)
	2013	Centennial Year of *Proceedings of RCA*

Proceedings of the IRE

Vol. 1 No. 1 of the new publication was 6×9½ inches (unlike today's 8×11 inches format) and contained only three articles:

- Pupin provided the transcript of a lecture he gave to TWI on "Experimental Tests of the Radiation Law for Radio Oscillators." Discussion notes followed from those commenting at the lecture; including Marriott, then Chief Engineer of the Wireless Company of America and the first President of the new IRE, and Goldsmith, a cofounder of the IRE and the first editor of its new *Proceedings*. Goldsmith also included his own "Editorial Notes" with further comments.
- Stanley M. Hills provided a review of "High Tension Insulators for Radio Communication" evaluating insulators for antennas and condensers. He reviewed glass, porcelain, mica, micanite, air, oil, and other patented products. Goldsmith and Marriott added Bakelite, Condensite, hard rubber, wood, and rope to the list of materials.
- Lee de Forest provided a transcript of his lecture given to the IRE in November 1912, at Columbia University, entitled "Recent Developments in the Work of the Federal Telegraph Company." De Forest identified Federal's stations and criticized the Poulsen arc generators. He argued that they were unreliable, suffered from inadequate cooling systems and had faulty insulation. The ensuing discussion included Goldsmith and Hogan (de Forest's former assistant and the co-founder of SWTE and IRE).

Vol. 1 No. 1 of the Proceedings of the IRE.

The remaining issues of Volume I were published in April, July, and December 1913. They included ten more articles written by Marriott, Hogan, Goldsmith, Pickard (the current President of the IRE), Roy Weagant (Marconi's chief engineer) and others. Marriott's article "Radio Operation by Steamship Companies" appeared one year after the *RMS Titanic's* survivors had been rescued by wireless. Weagant's article outlined "Some Recent Radio Sets of the Marconi Wireless Telegraphy Company of America." The *Proceedings* became a bimonthly publication in 1916, and a monthly publication in 1927.

Expansion Under the IRE

The IRE's stated goals included both the presentation and preservation of technical papers. It sought to publish all papers, discussions, and communications received from the membership; in contrast to the AIEE where the technical committees had sole charge of accepting or rejecting papers for presentation at regional or technical conferences, and a paper had to be presented before it was published in the *Transactions.* As a result, many extraordinary visionaries published in the IRE's journal, in fields that expanded the scope far beyond radio; including Edwin H. Armstrong, de Forest, Grace Hopper, Guglielmo Marconi, John Mauchly and Vladimir Zworykin.

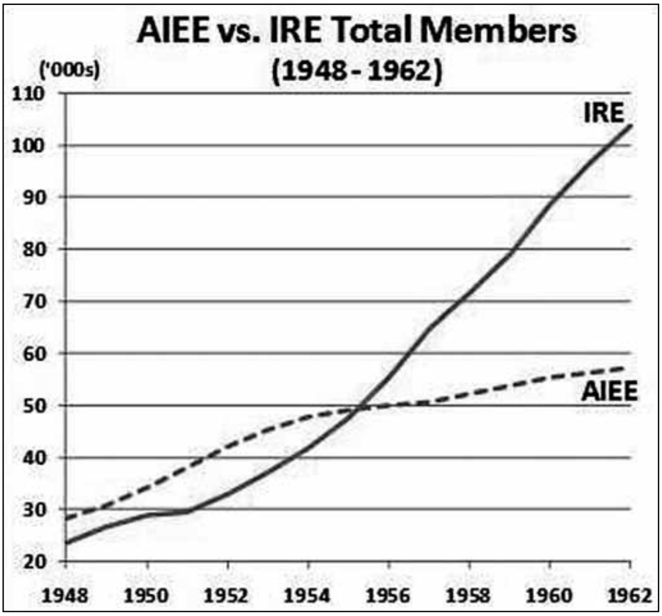
The IRE's policy of rapid publication was based on its scientific orientation where an early publication date established a priority claim over new principles and discoveries. Its papers were refereed and selected in a rigorous and discriminating peer-review process modeled on the procedures of scientific journals. The *Proceedings* quickly gained a reputation of publishing only the best authors, who considered it a unique honor to appear in this journal. The authors, would achieve, or already had achieved, reputations as leading authorities in their field based, in part, on their contributions to the *Proceedings.*

By the late 1940s, the *Proceedings* in large part resembled its current format. Papers continued to be peer-reviewed prior to acceptance. Goldsmith, still serving as editor of the *Proceedings*, sought papers of general interest to a broad spectrum of the membership. More arcane papers on narrow topics were directed to the IRE's separate publications, the *Transactions,* issued by its separate technical interest groups.

In 1954, John Pierce, the director of electronic research at Bell Labs, succeeded Goldsmith as editor. Pierce began relying on specialist reviewers to authenticate the articles. He also sought to make the increasing technical content more comprehendible to engineers outside each sub-field of expertise. Each issue now regularly exceeded 100 pages. Pierce also encouraged correspondence, including rebuttals and surrebuttals. In May 1962, the IRE published a 1,000 page special issue celebrating the organization's 50th anniversary.

Proceedings of the IEEE

The competition for membership between the AIEE and the IRE created tensions between the two organizations from the IRE's inception in 1912. In 1937, the IRE adopted its own technical committee structure for the first time; with the first six committees encompassing broadcast, electroacoustics, radio receiving, television and facsimile, transmitting and antennas, and wave propagation. By 1948, declines in AIEE student membership and student branches were indicative of its future direction. In 1956, student membership at the IRE propelled past the AIEE. The total membership of the IRE moved ahead the next year, with dramatic growth occurring over the next few years.

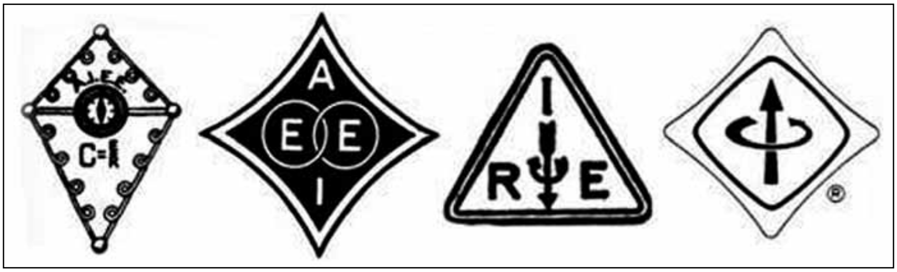


Total Members in IRE and AIEE. (Courtesy, IEEE, Membership Statistics, 1962.)

In 1963, the IRE merged with AIEE. By then, the AIEE and the IRE each published their own journals; the various *Transactions* by the AIEE, and the *Proceedings* by IRE. The combined organization recognized the importance of providing a premier publication, and introduced the *Proceedings of the IEEE* as its primary journal.

In January 1964, the IEEE also established the *IEEE Spectrum*, modeled on the AIEE's former *Electrical Engineering,* as a more general magazine accessible to non-specialists. The *Spectrum* addressed general technology and science trends pertaining to electrical and electronics engineering, mechanical and civil engineering, computer science, biology, physics and mathematics. Each of the IEEE's sub-groups also began publishing. Today, the IEEE produces over 30% of the world's literature in the electrical and electronics engineering and computer science fields, issuing 150 separate peer-reviewed journals.

Since 1963, the *Proceedings of the IEEE* has maintained the general format of its predecessor publication; however, members were soon required to pay additional fees to receive the journal, since it was no longer included as a membership benefit. In contrast to its predecessor, the *Proceedings* published monthly, not quarterly. Today's *Proceedings* also include lengthy prologues to introduce the subject themes of the issue. This style of introducing the topic contrasted with the after-article 'discussions' and debates about the author's findings found in earlier issues.



Evolution of the IEEE Logo: AIEE, IRE, IEEE. (Courtesy IEEE History Center).

The *Proceedings* continued to draw upon the diverse and specialized resources of the IEEE's membership, and occasionally beyond the IEEE. As technology evolved and the membership encompassed former members of both the IRE and AIEE, the scope of the publication's topics expanded beyond radio and wireless. Disparate fields gradually converged into new specialties with unprecedented applications. The *Proceedings of the IEEE*, with its coverage across all boundaries, continued to flourish, ranking as one of the most highly cited general-interest journals in electrical and computer engineering. It remains one of the most highly cited IEEE publications.

IEEE's ComSoc Publications

The tremendous interest in IEEE's publications relating to communications followed the dramatic growth of a vast, highly technical communications industry. IEEE's publications specializing in communications continued to undergo substantial change coinciding with the evolution of the IEEE Communications Society (ComSoc).

ComSoc was initially founded in 1952 as the IRE's Professional Group on Radio Communications. It was renamed later that year as the Professional Group on Communications Systems (PGCS). ComSoc operated as a semi-autonomous group and became an independent IEEE society in 1972. Beginning that year, the decade old *IEEE (formerly IRE) Transactions on Communications* evolved from a quarterly to bimonthly to monthly publication. An additional publication, the *IEEE Journal on Selected Areas in Communications*, was "spun-off" in 1982. The *Journal* became a monthly publication in 1999 with the addition of the Wireless Communications Series. In 2002 the WCS became the *IEEE Transactions on Wireless Communications*, published quarterly.

In 1982, the *Transactions* and the *Journal* were 'unbundled' from the dues structure and made available to both members and non-members. In 1993, ComSoc introduced the *IEEE/ACM Transactions on Networking*, and in 1996, another new publication appeared, the *IEEE Communications Letters*. ComSoc's first electronically published journal, the *IEEE Communications Surveys & Tutorials*, started in 1996.

TABLE 2. IEEE COMSOC PUBLICATIONS
IEEE/ACM Transactions on Networking
IEEE Communications Letters
IEEE Communications Surveys & Tutorials
IEEE Transactions on Wireless Communications
IEEE Journal on Selected Areas in Communications
IEEE Transactions on Communications
IEEE Communications Interactive (Online)
IEEE Communications Magazine; formerly,
• *IEEE Communications Society Newsletter*
• *IEEE ComTech Newsletter*
• *IRE PGCS Newsletter*
IEEE Wireless Communications; formerly,
• *IEEE Personal Communications*
IEEE Network—The Magazine of Global Information Exchange

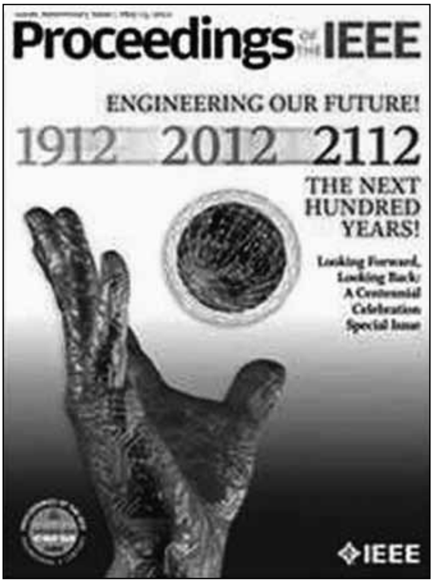
The original *IRE PGCS Newsletter* evolved into the *IEEE ComTech Newsletter* which then became the *IEEE Communications Society Newsletter.* In 1975, the *Newsletter* expanded, becoming the *IEEE Communications Magazine* with the addition of general technical interest features. It became a monthly publication in 1983, and in 1997, it went online with *IEEE Communications Interactive.*

ComSoc also produced the *IEEE Network—The Magazine of Global Information Exchange* beginning in 1987, and *IEEE Personal Communications* (now *IEEE Wireless Communications*) first appeared in 1994. ComSoc co-sponsors, with other IEEE Societies, other publications including *IEEE Internet Computing*, *IEEE Multimedia Magazine*, *IEEE Transactions on Applied Superconductivity*, *IEEE/OSA Journal of Lightwave Technology*, *IEEE Transactions on Multimedia*, *IEEE Pervasive Computing*, *IEEE Sensors Journal* and *IEEE Transactions on Mobile Computing.*

The full range of IEEE's resources available to those interested in electronic and electrical communications continues to expand.

Centennial

In May 2012, the IEEE published a Centennial Special Issue of the *Proceedings* that included history, current developments and speculation about future developments in 20 areas of interest, ranging from neuro-technological systems to home electronics.



Centennial Issue of Proceedings of the IEEE, May 2012. (Courtesy of IEEE).

Proceedings of the IEEE Centennial Logo. (Courtesy of IEEE.)

The IEEE celebrated the centennial of the original *Proceedings* by reproducing Classic Papers from the past 100 years. The papers were published under both the IEEE and its predecessor, the IRE. The IEEE identified these Classic Papers as the most influential articles in the field of electrical and electronics engineering. During the 24 months spanning 2011–2012, the *Proceedings* republished 24 Classic Papers, one in each issue.

In addition, the staff of the IEEE History Center authored ten articles, surveying the technological developments for each decade from 1912–2012 that were related to IRE, the IEEE and the *Proceedings*. These survey articles provide many insights into the leading developments as well as their connections to the inventors and scientists that left their mark in the field.

Table 3 summarizes those articles from the IEEE's Classic Papers that relate to radio and wireless communications. The table identifies featured authors, articles about their contributions, and the seminal articles those authors published in the *Proceedings* that were selected as Classic Papers.

Most of the Classic Papers are referenced by separate historical articles that describe the significance of the paper and the author's contributions to the field. The subject matter includes critical developments in vacuum tubes, feedback circuits, early television, waves, transistors, satellites, radiation, telegraph and radio-telegraphy, broadcast transmission, receivers, and early computers. Those interested in understanding the foundations of today's electronics applications are encouraged to reach back and to review some of these seminal writings.

TABLE 3. IEEE CLASSIC PAPERS RELATING TO RADIO 1912–2012		
Featured Author	***Articles About The Featured Author***	***Classic Paper (Shown With Reprint Date)***
Vladimir K. Zworykin December 2012	James E. Brittain, "Electrical Engineering Hall of Fame: Vladimir K. Zworykin," Proc. IEEE, vol. 97, no. 3, pp. 594-597, March 2009.	Vladimir K. Zworykin, "The Iconoscope—A Modern Version of the Electric Eye," Proc. IEEE, vol. 22, no. 1, pp. 16-32, Jan. 1934.
Hendrik van der Bijl November 2012	Dirk J. Vermeulen, "The Remarkable Dr. Hendrik van der Bijl," Proc. IEEE, vol. 86, no. 12, Dec 1998.	H.J. van der Bijl "Theory and Operating Characteristics of the Thermionic Amplifier," Proc. IEEE, vol. 7, no. 2, pp. 97-128, April 1919.
F.E. Terman October 2012		F.E. Terman, "Some Applications of Negative Feedback with Particular Reference to Laboratory Equipment," Proc. IEEE, vol. 27, no. 10, pp. 649-655, Oct. 1939.
Charles P. Steinmetz September 2012	Saifur Rahman, "An Introduction to "America's Energy Supply" by C. P. Steinmetz," Proc. IEEE, vol. 86, no. 4, pp. 721-722, Apr. 1998.	Charles P. Steinmetz, "America's Energy Supply," Proc. IEEE, vol. 86, no. 4, pp. 723-734, Apr. 1998.
George C. Southworth August 2012	James E. Brittain, "Electrical Engineering Hall of Fame: George C. Southworth," Proc. IEEE, vol. 98, no. 10, pp. 1787-1790, Oct. 2010.	George C. Southworth, "Some Fundamental Experiments with Wave Guides," Proc. IEEE, vol. 87, no. 3, pp. 515-521, Mar. 1999.
William Shockley July 2012	T.H. Ning, "On Shockley's 1952 Proceedings of the IRE paper," Proc. IEEE, vol. 85, no. 12, pp. 2052-2054, Dec. 1997.	W. Shockley, "Transistor electronics: imperfections, unipolar and analog transistors," Proc. IEEE, vol. 81, no. 12, pp. 2055-2080, Dec. 1997.
Claude E. Shannon June 2012		A.D. Wyner and S. Shamai, "Introduction to 'Communication in the presence of noise'," Proc. IEEE, vol. 86, no. 12, pp. 442-446, Feb. 1998.
		C.E. Shannon, "Communication in the presence of noise," Proc. IEEE, vol. 86, no. 2, pp. 447-457, Feb. 1998.

TABLE 3. IEEE CLASSIC PAPERS RELATING TO RADIO 1912–2012		
Featured Author	***Articles About The Featured Author***	***Classic Paper (Shown With Reprint Date)***
John R. Pierce May 2012	J.E. Brittain, "Electrical engineering hall of fame: John R. Pierce," Proc. IEEE, vol. 98, no. 3, pp. 493-496, Mar. 2010.	J.R. Pierce and R. Kompfner, "Transoceanic communication by means of satellites," Proc. IEEE, vol. 85, no. 6, pp. 1011-1019, Jun. 1997.
Michael I. Pupin April 2012	J.E. Brittain, "Electrical engineering hall of fame: Michael I. Pupin," Proc. IEEE, vol. 93, no. 6, pp. 1224-1226, Jun. 2005.	M.I. Pupin, "A discussion on experimental tests of the radiation law for radio oscillators," Proc. IEEE, vol. 85, no. 2, pp. 306-310, Feb. 1997.
B. M. Oliver March 2012	Biography of B.M. Oliver from Proc. IRE, vol. 50, no. 2, pp. 234, Feb. 1962.	B.M. Oliver, "Some potentialities of optical masers," Proc. IRE, vol. 50, no. 2, pp. 135-141, Feb. 1962.
Harry Nyquist February 2012	J.E. Brittain, "Electrical engineering hall of fame: Harry Nyquist," Proc. IEEE, vol. 98, no. 8, pp. 1535-1537, Aug. 2010.	H. Nyquist, "Certain topics in telegraph transmission theory," Proc. IEEE, vol. 90, no. 2, pp. 280-305, Feb. 2002.
Senatore Guglielmo Marconi January 2012	J.E. Brittain, "Electrical engineering hall of fame: Guglielmo Marconi," Proc. IEEE, vol. 92, no. 9, pp. 1501-1504, Sep. 2004.	S.G. Marconi, "Radio telegraphy," Proc. IEEE, vol. 85, no. 10, pp. 1526-1535, Oct. 1997.
D.G. Little December 2011	M.A. Simaan, "An introduction to D. G. Little's 1924 classic paper 'KDKA'," Proc. IEEE, vol. 86, no. 6, pp. 1273-1278, Jun. 1998.	D.G. Little, "KDKA: The radio telephone broadcasting station of the westinghouse electric and manufacturing company at East Pittsburgh, Pennsylvania," Proc. IEEE, vol. 86, no. 6, pp. 1279-1287, Jun. 1998.
Irving Langmuir November 2011	J.E. Brittain, "Electrical engineering hall of fame: Irving Langmuir," Proc. IEEE, vol. 98, no. 12, p. 2252-2254, Dec. 2010.	I. Langmuir, "The pure electron discharge and its applications in radio telegraphy and telephony," Proc. IEEE, vol. 85, no. 9, pp. 1496-1508, Sep. 1997.
K.G. Jansky October 2011	J.E. Brittain, "Scanning the past: Karl G. Jansky," Proc. IEEE, vol. 81, no. 10, p. 1538, Oct. 1993.	K. Jansky, "Electrical disturbances apparently of extraterrestrial origin," Proc. IEEE, vol. 86, no. 7, pp. 1510-1515, Jul. 1998.

TABLE 3. IEEE CLASSIC PAPERS RELATING TO RADIO 1912–2012		
Featured Author	***Articles About The Featured Author***	***Classic Paper (Shown With Reprint Date)***
R.A. Heising September 2011	D. Messerschmitt, "Introduction to the classic paper by R.A. Heising," Proc. IEEE, vol. 85, no. 5, pp. 747-751, May 1997.	R.A. Heising, "Production of single sideband for trans-Atlantic radio telephony," Proc. IEEE, vol. 85, no. 5, pp. 752-761, May 1997.
Robert M. Fano August 2011	L. Lessig, "Change and choices: Introduction to 'On the social role of computer communications,'" Proc. IEEE, vol. 87, no. 12, pp. 2127-2129, Dec. 1999.	R.M. Fano, "On the social role of computer communications," Proc. IEEE, vol. 87, no. 12, pp. 2130-2135, Dec. 1999.
J. Presper Eckert July 2011	P.B. Schneck, "Introduction to the classic paper: A survey of digital computer memory systems, a modern review of the paper by Eckert," Proc. IEEE, vol. 85, no. 1, pp. 181-183, Jan. 1997.	J.P. Eckert, "A survey of digital computer memory systems," Proc. IEEE, vol. 96, no. 1, pp. 184-197, Jan. 1997.
John H. Dellinger June 2011	J.E. Brittain, "Electrical engineering hall of fame: John H. Dellinger," Proc. IEEE, vol. 95, no. 9, pp. 1884-1887, Sep. 2007.	J.H. Dellinger, "Principles of radio transmission and reception with antenna and coil aerials," Proc. IEEE, vol. 87, no. 5, pp. 894-921, May 1999.
Alfred N. Goldsmith May 2011	J.E. Brittain, "Electrical engineering hall of fame: Alfred N. Goldsmith," Proc. IEEE, vol. 96, no. 2, pp. 366-370, Feb. 2008.	A. Goldsmith, "The genesis of IRE," Proc. IEEE, vol. 40, no. 5, pp. 516-520, May 1952.
Lee de Forest April 2011	J.E. Brittain, "Electrical engineering hall of fame: Lee de Forest," Proc. IEEE, vol. 93, no. 1, pp. 198-202, Jan. 2005.	Lee de Forest, "The audion – detector and amplifier," Proc. IEEE, vol. 86, no. 9, pp. 1881-1888, Sep. 1998.
John G. Brainerd March 2011	J.E. Brittain, "John G. Brainerd and project PX (ENIZC)," Proc. IEEE, vol. 84, no. 3, p. 502, Mar. 1996.	J.G. Brainerd and T.K. Sharpless, "The ENIAC," Proc. IEEE, vol. 87, no. 6, pp. 1031-1041, Jun. 1999.
Harold S. Black February 2011	J.E. Brittain, "Electrical engineering hall of fame: Harold S. Black," Proc. IEEE, vol. 99, no. 2, pp. 351-353, Feb. 2011.	H.S. Black, "Stabilized feed-back amplifiers," Proc. IEEE, vol. 87, no. 2, pp. 379-385, Feb. 1999.

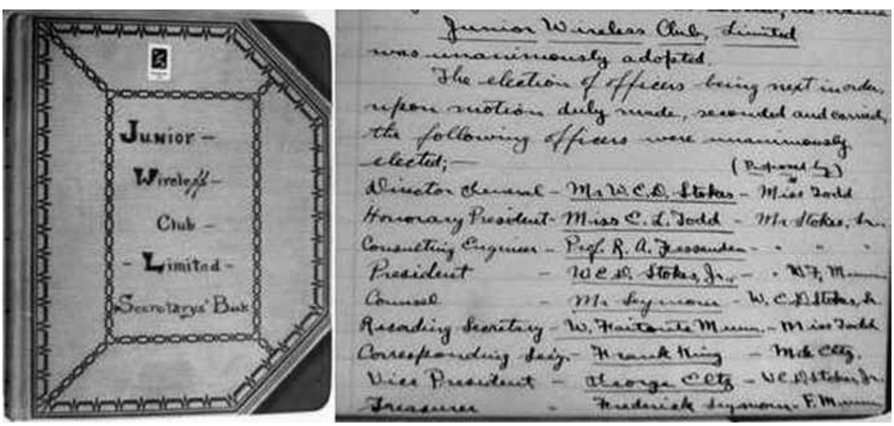
TABLE 3. IEEE CLASSIC PAPERS RELATING TO RADIO 1912–2012		
Featured Author	***Articles About The Featured Author***	***Classic Paper (Shown With Reprint Date)***
Edwin H. Armstrong January 2011	J.E. Brittain, "Electrical engineering hall of fame: Edwin H. Armstrong," Proc. IEEE, vol. 92, no. 3, pp. 575-578, Mar. 2004.	E.H. Armstrong, "Some recent developments in the audion receiver," Proc. IEEE, vol. 85, no. 4, pp. 686-697, Apr. 1997.

PART II — THE PROCEEDINGS OF THE RCA

The Radio Club of America was originally intended, and remains known today, as a premier gathering place, or forum, for those interested in all aspects of radio; its science, technology, development, and the art of broadcast. RCA's membership encompasses people interested in not just radio, but in all of its applications; including television, computers, paging, land mobile radio, public safety, internet, telephone, wireless and modern cellular and digital communications. Over the years, RCA has attracted many of the best and brightest technology leaders. Its primary publication, the *Proceedings of the RCA*, spotlights topics that RCA's members considered relevant to the development of radio and wireless communications.

Origins

RCA was founded in 1909 as the Junior Aero Club by a group of boys seeking adventure and led by E. Lillian Todd, a self-taught inventor and the first woman to design airplanes. Almost overnight, it became the Junior Wireless Club,



First RCA Minute Book Dated 1909.

Ltd. with Professor Reginald Fessenden as Consulting Engineer. In October 1911, the organization renamed itself The Radio Club of America to reflect its new focus. RCA is the world's oldest surviving radio communications society, or club.

By 1912, the IRE focused on the new fields of wireless telegraphy and radio as a professional association. Two years later, the American Radio Relay League (ARRL) formed to promote the interests of the growing number of amateur radio operators.

In contrast, RCA quite intentionally remained a club, attracting both professionals and amateurs to its activities. RCA operated as a blend of professional society and amateur experimenter's association. RCA effectively bridged the gap between the amateurs and professionals, but remained a smaller entity that sought to promote cooperation among enthusiasts interested in the advancement and study of radio communications. RCA's focus was different than IEEE's. It was not a large, international, professional organization. Over time, RCA's focus remained on experimentation, and many seminal papers were shared among the wide variety of important industry leaders who participated in RCA's meetings.[4]

Within a few short years, RCA evolved into a primary gathering place for leading inventors, developers, amateurs and enthusiasts to meet and share ideas in an environment that was less formal than professional associations such as the IRE, the AIEE, or their successor organization, the IEEE, and less political than ARRL.

RCA's members initially prepared papers and led technical discussions at a time when little information was available for those interested in these topics. The Annual Banquet, which began in 1919, became a place for members to recognize and celebrate their work. Over the years, RCA's membership grew to include many venerable names associated with important accomplishments in the development of radio communication as shown in Table 4.

At the outset, RCA's membership could largely be considered amateurs since commercial radio communication was still in its infancy, and formal regulation, professional training and university education had not yet emerged in the field. When governmental regulation did begin, RCA's members all held amateur or professional radio operator licenses. Today, most members continue to maintain their licenses.

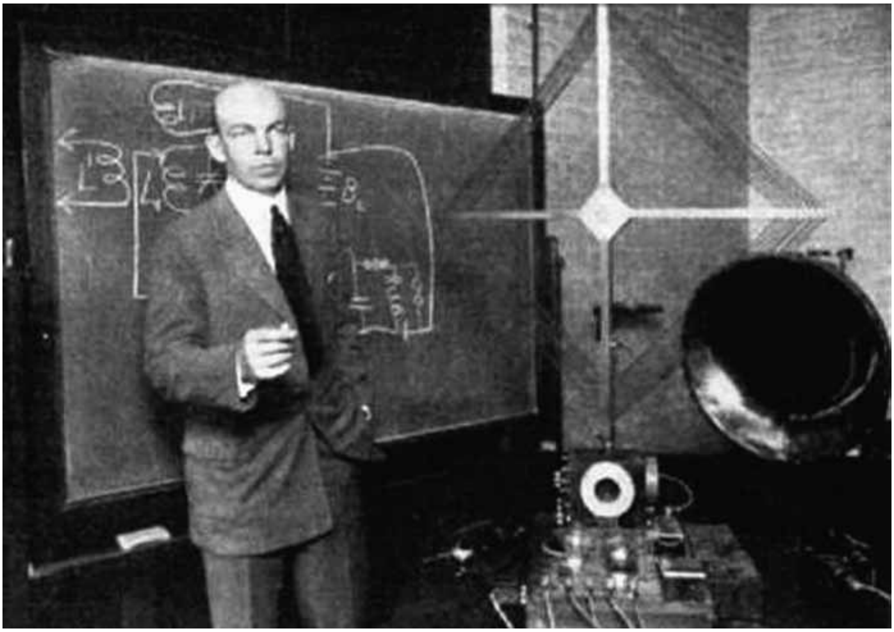
The Proceedings of the RCA

Under the direction of President Frank King, the first President of RCA, the club became the first organization to publish an Amateur Radio Call Book in 1912; and since 1914, RCA has regularly published lists of its members. King built and operated the first amateur telephone station in the U.S. using an arc transmitter. He also organized, and was Officer in Charge of, the first U.S. Aircraft Naval Radio Laboratory.

Prior to 1913, individual technical papers presented at RCA's meetings

TABLE 4.
SOME IMPORTANT RADIO CLUB OF AMERICA MEMBERS

• W.E.D. Stokes – Founder of RCA	• William Lear – Electronics and Lear Jet
• Jack Binns – 1st Wireless Distress CQD	• John Louis Hazeltine – Neutrodyne Circuit
• Prof. R.A. Fessenden – Radio Transmission	• John V.L. Hogan – Single Dial Tuning
• Harry Houck – Armstrong's Collaborator	• David Sarnoff – Radio Corp. of America
• Paul Godley – Mobile Radio	• Frank Gunther – Short Wave Radio
• Edwin H. Armstrong – Key Radio Circuits	• Fred M. Link – Two-Way Radio
• Lee DeForest – Audion Radio Tube	• John Poppele – Transmitters / Voice of America
• Alan B. DuMont – Cathode Ray Tube	• Morgan O'Brien – Founder of Nextel
• Robert H. Marriott – 1st Pres. IRE (IEEE)	• Martin Cooper – Motorola Cell Phones
• Art Collins – Founder Collins Radio Co.	• Jim Larsen – Larsen Antennas
• Walter Chronkite – CBS News Anchor	• Bill Eitel – Eitel-McCullough (EIMAC Tubes)
• Sen. Barry Goldwater – U.S. Senate	• Bill Halligan – Hallicrafters Company
• Fred Link – Link Radio Corp. Police Radio	• Jack McCullough – EIMAC Tubes



Edwin H. Armstrong's Presentation at RCA about the Regenerative Circuit in 1919. (Courtesy RCA.)

were simply reprinted for the membership. In the early years, papers discussed at RCA's meetings were also published by *QST*, *Radio Broadcast*, *Electrical World* or other leading magazines and journals. RCA distributed Edwin H. Armstrong's "Theory of Tuned Circuits" in May and December 1913 as the first article associated with a specific issue date of the *Proceedings of the RCA*. This paper represents the formal first year of publication.

The list of RCA's forty-four members, issued in 1914, is the earliest surviving publication that featured RCA's name. It includes designations of pending radio licenses, the type of equipment used and the member's evening and weekend hours of operation.

That year, eight more papers were presented at RCA's meetings which were soon published as issues of RCA's *Proceedings*.

Early issues of RCA's *Proceedings* reported T. Johnson, Jr. as the Editor. RCA suspended operations during World War I, including its distribution of articles and papers. In January 1920, RCA resumed publication of the *Proceedings*, naming W.S. Lemmon as Editor-in-Chief, and E.V. Amy, A. Lescaboura and L. Spangenberg as Assistant Editors. A. Lescarboura was the managing editor of *Scientific American*. Later, Pierre Boucheron would provide editorial support as head of advertising and public relations for the Radio Corporation of America.

Frank King, RCA co-founder and the President responsible for RCA's first publications. (Courtesy RCA.)

Ernest V. Amy, RCA co-founder and President who made significant editorial contributions to the Proceedings of the RCA. (Courtesy RCA.)

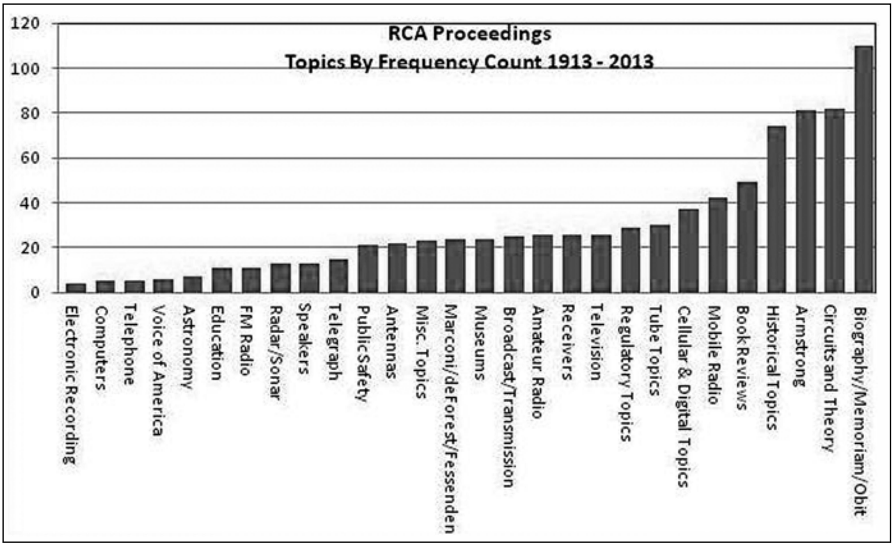
Amy continued to be involved in an editorial capacity for many years and also served as an RCA President. He designed and constructed the antenna for the 1BCG transmitter which sent the first radio message ever to be received across the Atlantic Ocean on short waves. He also developed early vacuum tube transmitters for commercial marine use, high power short wave transmitters and directional antennas and multi-coupler master antenna systems used in FM and TV broadcasting.

Over the next 60 years, many editors and assistant editors made their contributions to the *Proceedings*; guiding its subject matter and formats, and selecting the number of papers published in each issue based, in part, on their success in recruiting a range of authors.

The Evolution of Relevant Topics

From the beginning, RCA's meetings offered a chance to present and discuss leading developments freely and openly in an exchange of ideas among interested participants, regardless of their formal background. All of the authors are considered leaders in their fields; some in academia, others in business, and many are historians. Many of the authors are leading inventors and technical developers. In more recent years, many have been involved in regulatory work and public safety issues. Indeed, RCA's *Proceedings* has served as a unique publication, offering a mix of technical articles, often with comments about technical presentations.

During the century of its existence, the *Proceedings* published almost 2,100 articles, announcements and news items. The *Proceedings* included considerable biographical material about RCA's members through feature stories, awards, memorials and obituaries and significant coverage of historical topics. Much of this material is unique,



offering historians a wealth of information about key figures and their contributions to our modern world.

Over its 100 years, the subject matter in the *Proceedings* expanded from radio to all forms of electronic and electrical communication including current work in telephony, television, cellular, digital, and modern wireless communication. The scope shifted over time from science and invention to include manufacturing, development, marketing and a search for other applications as well as relevant standards. Topics also included the art of broadcasting and the application of radio across public, governmental, military and safety arenas. The articles soon ranged from highly technical analyses to more accessible discussions and descriptions about general subjects.

As the full understanding of radio and its various applications expanded, the *Proceedings* eventually included related topics such as the history of electrical communication in telegraphy and telephony, the evolution of television, satellites, land mobile radio, paging systems, and eventually, new cellular and digital technologies used in today's wireless world.

Shifting Focus

In the early years, the *Proceedings* focused on circuit development and evolution of new radio tubes as well as new regulatory standards:

- "Navy Receiving Equipment" by L.C.F. Horle in 1920 shared information about the latest in governmental applications of radio.
- Edwin H. Armstrong published several articles on the regenerative, heterodyne and super heterodyne circuits.
- "Tuned Radio Frequency Amplification With Neutralization of Capacity Coupling" by Louis A. Hazeltine in 1923 further advanced circuit design.
- C.L. Farrand explained "A Single-Control Receiver" and C.W. Hewlett introduced "An Induction Loud Speaker" in 1924.

Topics continued to widen into professional broadcasting and television, and even aircraft guidance, with articles such as:

- "Acoustics and Microphone Placing in Broadcast Studios" by Carl Dreher in 1928.
- "A Study of Sound Recordings" by C.F. Goudy and W.P. Powers in 1930.
- "A Practical Television System" by D.E. Replogle in 1930.
- Allen B. DuMont introduced his own "Practical Operation of a Complete Television System" in 1931.
- "Recent Development in the Guidance of Aircraft by Radio" by Harry Diamond in 1931.

In 1934, RCA published a special edition "25th Anniversary Yearbook", and the stage was set for the next 75 years. The scope of topics would continue to expand and the *Proceedings* would continue to feature leading articles.

The World War II era was marked by secrecy due to national security concerns. After the war, Jerry Minter and others unveiled the story of the proximity fuze, one of the leading technological developments of armed conflict. Topics continued to expand into satellites, deep space, and computer-produced movies by the mid-1960s. Fred Link documented "From Drums to Mobile Radio (A History of Mobile Radio Communications)" in 1968. Microwave antennas and cellular developments followed.

The *Proceedings* included information on the annual banquet and biographies about award recipients. With time, historical topics emerged and RCA covered museum preservation efforts. As the century closed, obituaries and memorials also provided considerable information about the membership and their noteworthy lives.

About the Authors

Historically, the authors featured in the *Proceedings* included legendary figures of radio and communications including Armstrong, Hogan and Marriott. Leading figures in mobile communications, including Martin Cooper, Jerry Minter and Frank Gunther, were also frequent writers. In these pages, RCA's founders and prominent leaders shared their views on current topics, and their perspectives on the future. Over the years, the *Proceedings* have also documented RCA's own history and the contributions of this small but unique organization.

RCA's current membership focuses on two-way radio in public safety applications, television broadcasting,

First Cover Illustration for the RCA Proceedings in May, 1986 showing 'Alexanderson Alternator at Radio Central' with E.F.W. Alexanderson.

wireless messaging, satellite Global Positioning System technology, paging systems, wireless voice and data systems, cellular and digital applications, Internet and smart phone technologies, and even cognitive radio.

RCA's leaders continue to be active in leading research and development of 4G wireless network standards for mobile video and high-speed wireless data services and Long Term Evolution (LTE) technology. For example, RCA's Ted Rappaport is responsible for establishing three of the largest wireless academic research centers at the University of Texas at Austin, Virginia Tech and New York University. He holds over 100 patents for applications of radio wave propagation for cellular and personal communications, wireless communication system design, and broadband wireless communications circuits and systems at millimeter wave frequencies. RCA member Nathan Cohen is the leading authority on fractal antennas and RF cloaking devices. He holds 28 patents on ultrasound and medical devices; real-time de-convolution; compression; image processing; antennas; and fractal engineering. RCA member, Martin Cooper, is the 'father' of the Motorola handheld portable cell phone, and widely recognized as an innovator in radio spectrum management.

A Range of Formats and Publications

Over the years, the *Proceedings* have varied in format; from single reprints of papers to a more formalized publication. Today, the *Proceedings* have a modern, less formal magazine style format. The frequency of the *Proceedings* has also varied from meeting reprints, to monthly, quarterly, semi-annual publication and even annual yearbooks. On the 25th, 50th and 75th anniversaries, RCA published yearbooks as expanded editions of its *Proceedings* that contained detailed histories of the club and its members' accomplishments. RCA also issued commemorative *Proceedings* as books detailing "The Story of the First Trans-Atlantic Short Wave Message" in the fall of 1950, and "The Legacies of Edwin Howard Armstrong" in November 1990.

Some of RCA's Other Publications Issued Under the Proceedings.

Centennial

Since 1913, RCA's *Proceedings* has provided a window into the organization and a view into RCA's much heralded membership and their activities. Taken as a whole, the *Proceedings* documented critical and important developments in the evolution of modern electronic communications involving radio. They also preserved important historical information about other major technological advances involving electronic communications and their applications as well as biographical material about RCA's members.

RCA Centennial CD Issued in 2009 With Copies of the RCA Proceedings.

RCA celebrated its centennial in 2009. In conjunction with that centennial, RCA scanned all existing copies of its *Proceedings* up to 2009 onto CD for electronic preservation and distribution to its members and researchers. To commemorate the centennial of the *Proceedings*, the organization compiled a comprehensive index of all surviving copies of the *Proceedings* from 1913 through 2013. That index includes an introduction to RCA, a history of the *Proceedings* itself, listings of notable RCA inventors and developers, an index to RCA's awards, and photos of some important RCA milestones. RCA continues to work with the AWA to preserve its important records and archives.[5]

PART III — LEGACIES

The Institute and the Club

The IRE offered a formal environment for academic and technical presentations as well as a larger, international membership. In contrast, the ARRL operated with a political focus on preserving the rights of amateurs as well as offering a place for amateurs to share information about new products and ideas, operating tips and technical education to satisfy licensing requirements. Although the IRE and its successor, the IEEE, served professionals, and the ARRL served amateurs, RCA always sought a more unique identity as a club.

All of these organizations provided locations for technical presentations; but, RCA sought from the outset to attract the best and brightest from all three worlds. By design, RCA brought together leading amateurs, professionals and academics under one roof in a more collegial forum that broke down barriers. RCA invited members with varied backgrounds to participate and share their knowledge and interests in the new technology and its applications. RCA remained the smaller organization, whereas the IEEE became the largest professional association of its kind, capable of serving not just the radio and wireless fields, but all of electronics and electrical engineering.

Over the years, academics, industry leaders, amateurs and historians have all shared their ideas and made contributions to both the IEEE and RCA. Goldsmith, Hogan, Marriott, Pupin, Henry J. Round, Brigadier General David Sarnoff, John Stone Stone, and Professor Jonathan Zenneck were all members of RCA, and most were members of the IRE. In fact, Hogan, Marriott and Stone were among the co-founders of the IRE, and in 1912, Marriott was its first President. Goldsmith edited the *Proceedings of the IRE* for an incredible forty-two years. Armstrong's super heterodyne receiver from 1912 is considered by many to be the most significant of all early radio technologies; and, Armstrong was active in RCA for nearly thirty years. Fessenden, responsible for first conceiving the heterodyne principles in 1902 prior to the advent of vacuum tubes, was RCA's first consulting engineer. Even today, Hogan's insights in his 1913 paper from the *Proceedings of the IRE* and his 1914 article from the *Proceedings of the RCA* discussing the significance of radio technology remain relevant, more than 100 years after publication.

Today's Organizations

The IEEE is now the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE has more than 430,000 members in more than 160 countries organized into 333 Sections in ten geographic regions worldwide. IEEE also has 38 Societies and ten technical Councils representing the wide range of IEEE technical interests.[6] The IEEE Communications Society (ComSoc) alone has 50,000 members worldwide. The IEEE now publishes approximately 150 transactions, journals and magazines.

Membership in IEEE is open to individuals who, by education or experience, give evidence of competence in an IEEE designated field. The designated fields are: Engineering, Computer Sciences and Information Technology, Physical Sciences, Biological and Medical Sciences, Mathematics, Technical Communications, Education, Management, and Law and Policy. IEEE offers the following grades of membership: Student, Graduate Student, Associate, Member, Senior Member, and Fellow. Special categories of Life Member, GOLD Member, and Society Affiliate are also offered.

In contrast, RCA has continued to maintain its identity as a club. It continues to publish the *Proceedings of the RCA* as well as the *Aerogram* and *RCA E-News*. Membership stands at approximately 1,000 members. RCA's activities include participation at many other leading industry associations such as CTIA, APCO, PCIA, UTC and IWCE.[7] RCA holds an annual awards banquet and technical symposium, makes awards to leading communications industry leaders, and operates an educational scholarship program.

Membership in RCA is open to anyone who is actively involved in the wireless or broadcast industry and who will commit to advancing the causes of the club. Membership applications are typically sponsored by existing members, but sponsorship is not required. RCA's causes include promoting, protecting and encouraging the study, practice and knowledge of wireless communications; granting scholarships to worthy students; disseminating this knowledge by talks, workshops, seminars and publications; and, encouraging the highest ideals of professionalism and ethical standards. RCA offers the following grades of membership: Regular, Retired, Student, and Corporate. Special categories of Life Member and Fellow are also offered.

Resources for Historical Research

Those interested in using the *Proceedings of the IEEE* or other IEEE resources for historical research should refer to the IEEE website.[8] Articles and abstracts are available for both members and non-members of the IEEE, and non-members can purchase individual items. IEEE's search engines provide access to approximately 3.7 million documents; including conference publications, journals and magazines, books and ebooks, early access articles, standards, and education and learning publications. IEEE's search engines also include more than 500,000 items from other organizations such as the American Institute of Physics (AIP) and The Institution of Engineering and Technology (IET). In addition, the IEEE operates the IEEE Global History Network (GHN) containing millions of pages of additional historical content.[9] Both the GHN and the search engines for the *Proceedings* and other resources are maintained through the IEEE Xplore Digital Library.

Those interested in performing research related to RCA or the *Proceedings of the RCA* should refer to RCA's website.[10] A *Comprehensive Index to the Proceedings of the Radio Club of America for 1913-2013* is available on the website.[11] Back issues of the *Proceedings* are available on the *RCA Centennial CD* issued in 2009. Issues after 2009 are available in the members' only area of the website, along with copies of the *RCA Aerogram* and the *RCA E-News* from 2009 to date, plus available presentation materials from RCA's annual Technical Symposiums held since 2009.

Conclusion

Reviewing the full scope of both the IEEE and RCA *Proceedings* offers the reader an opportunity to see the evolution of electronic wireless communication through the eyes of its developers as they shared their discoveries and grappled with the issues inherent in designing and bringing forth new cutting-edge technologies. In many cases, the topics addressed were decades ahead of the products that eventually became available to the general public. In sum, these pages document a century of discovery and offer an important reference for the history of communications technology and the people who contributed to the field.

Endnotes

1. The AWA has a complete collection of the *Proceedings of the IRE* (IEEE's predecessor) and the *Proceedings of the RCA* in its archives. These are available for research requests.
2. For more information about the history of the IEEE and RCA, see also the "Origins Of The Edison Medal On Its 100th Anniversary" (*AWA Review,* 2009, Vol. 22) and "The Origins of the Institute of Electrical and Electronic Engineers' Medal of Honor" (*AWA Review,* 2011, Vol. 24).
3. The early history of the American electrical profession, the beginnings of American professional societies and the emergence of the AIEE are explained in Ryder and Fink, 1984; *Century of Electricals*, 1984; McMahon, 1984; and Israel, 1992.
4. RCA continues to conduct meetings, events and banquets, and it continues to publish. Examples of more recent awards include Martin Cooper, inventor of the first hand held Motorola cell phone, Jerry Stover for mobile radio and nationwide cellular telephone service, and Dr. Donald Cox for his work in cellular systems, communications satellites, and universal portable wireless services.
5. RCA's Historical Committee endeavors to preserve the history of RCA through document retention, artifact collection and publication of historical articles and resources about RCA. In 2008, RCA's historical archives were deposited at the AWA, including copies of the first century of the *Proceedings of the Radio Club of America*.
6. See IEEE statistics as of December 31, 2013 at http://www.ieee.org/about/today/at_a_glance.html.
7. CTIA-The Wireless Association (leading association for wireless carriers and their suppliers, as well as providers and manufacturers of wireless data services and products), APCO International (world's oldest and largest organization of public safety communications professionals), PCIA-The Wireless Infrastructure Association (trade association for carriers, infrastructure providers and professional services firms that own and manage more than 135,000 telecommunications facilities throughout the world), UTC Telecom-The Utilities Telecom Council (global trade association dedicated to creating a favorable business, regulatory, and technological environment for companies that own, manage, or provide critical telecommunications systems in support of their core business), and the IWCE-International Wireless Communications Expo.
8. See the *Proceedings of the IEEE* search tools at http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=5.
9. The IEEE GHN preserves and promotes the history of innovation in electrical, electronic, and computer technologies and allied disciplines. It is a wiki-based website designed for the public to browse and for IEEE members and professional historians to contribute their experience, knowledge, and insights. The site also serves as a central historical repository of all the achievements, ideas, and

first-hand knowledge of IEEE members, societies, councils and technical communities and as a central location for all materials related to IEEE's organizational history. See http://www.ieeeghn.org/wiki/index.php/Special:Home.

10. See www.radioclubofamerica.org.
11. The index includes an introduction to RCA, a history of the *Proceedings*, listings of notable RCA inventors and developers, an index to RCA's awards, and photos of some important RCA milestones. The index also includes instructions for using the electronic version of the files to do your own custom searches and sorts, as well as pre-sorted versions of the index by item, article, author and key subjects. See the RCA website at: http://www.radioclubofamerica.org/index.php?option=com_content&view=article&id=43&Itemid=145.

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About the Authors

David and Julia Bart live near Chicago. They are graduates of the University of Chicago (David: BA & MBA: Julia: BA) and Concordia University (Julia: MA). David handles corporate finance and valuation matters in complex commercial litigation and corporate bankruptcy cases. Julia teaches elementary school and is a reading specialist. They maintain a highly varied range of interests in electronics history, and have published numerous articles about telegraph, radio and broadcasting history. David is a Board member of the Antique Wireless Association, the Museum of Broadcast Communications in Chicago, the Radio Club of America, and the Antique Radio Club of Illinois. He is a Corresponding Member of the IEEE History Committee, and Chairman of: the AWA Press Committee, RCA Publications Committee and RCA Historical Committee.

David has made presentations to the New York Historical Society, the American Association of Physics Teachers and American Association for the Advancement of Science Joint AAPT/AAAS Meetings, the Antique Wireless Association and the Radio Club of America.

Julia is a contributing editor and advisor to the *AWA Review* and is Editor for the Antique Radio Club of Illinois' publications. A past Treasurer of ARCI, Julia plays an active role as a volunteer and advisor to the Board of Directors. Julia also provides advisory services to the Antique Wireless Association and has coauthored several peer-reviewed articles for the AWA, RCA and IEEE.

David and Julia's work on the IEEE Edison Medal and the IEEE Medal of Honor is included on the Institute of Electrical and Electronics Engineers' *Global History Network* website.

David and Julia Bart

Early History of Electrical Detection and Warning of Natural Disasters

Abstract

Electrical storms were the subject of study by the earliest electrical pioneers, Benjamin Franklin and Joseph Henry being among the most famous. It is fitting that the earliest electrical technologies were in turn applied to understanding severe weather as well as to other natural disasters, and used to mitigate their effects by warning of their approach. Electrical and computing technologies have greatly advanced our understanding, detection, and warning of impending natural disasters. Nonetheless, the ability to detect and warn the public have faced policy obstacles. For example, tornado warnings were long forbidden in the United States. This paper describes early telegraph weather warning networks, the invention of electric seismographs, and finishes with a brief description of the current DART tsunami warning buoys.

Prior to the invention of electrical forms of communication, warnings of natural disasters such as severe weather or a tsunami from an earthquake, travelled more slowly than the hazardous events themselves. Alerts were seldom able to reach towns or villages in the path of destructive events in time to save lives.

Fig.1. Tornado over Lebanon, Kansas in 1902.

Early Efforts

The invention of the telegraph stimulated the formation of networks of weather observers. Suggested in 1837 by James Espy of the Franklin Institute, such a network was initiated in the United States in 1847. Joseph Henry, who had conducted research on lightning while a professor at the College of New Jersey (later Princeton University), made storms and the problems of severe weather one of the Smithsonian Institution's priorities when he became its first Secretary in December of 1846.[1] Henry persuaded U.S. telegraph companies to transmit weather reports from volunteer observers at no cost, and by 1849 the Smithsonian's network numbered one hundred and fifty volunteer observers. By 1860, the network had grown to six hundred.

In France, the Observatoire de Paris began issuing daily weather maps in 1863. In July of 1868, Cleveland Abbe, Director of the Cincinnati Astronomical Observatory, wrote a letter to the Cincinnati Chamber of Commerce in which he referred to the value of the French example, and suggested a system of issuing storm warnings.[2] In the Midwestern United States, the most damaging storms were usually tornadoes. So far, the telegraph had been used to carry warnings issued by human observers. However, there were also people who thought that the electrical devices could automatically generate the warnings as well.

Tornado Warning Systems

In 1883, astronomer Edward Holden proposed an automated electrical tornado warning system. His system would consist of an arc of telegraph poles to the south and west (i.e. the directions tornadoes appeared from) of towns and cities in tornado-prone areas. A wire would be strung along them, terminating in the town's telegraph office. Local connections from the office would reach into each home in the town. A current would hold an electromagnet magnet open as long as the wire was intact. If an approaching tornado snapped the wire, the current would cease, and the electromagnet release a clapper powered by a coiled spring which would ring a bell in each home, warning the residents to take shelter.[3]

The use of the word "tornado" in weather forecasts was banned in the United States from 1885 to 1938 for fear of panicking the populace, or that it might discourage people from settling in tornado-prone areas.[4] "Forecasts of tornadoes are prohibited" stated the Weather Bureau Stations regulations of 1905, and the prohibition was reiterated in 1915 and 1934. Business owners complained of the financial losses tornado warnings caused when customers and employees stayed home because of inclement weather.[5]

Even after an experimental tornado warning program began using radio in St. Louis, Kansas City, MO and in Wichita, KS, in the spring of 1943, H.M. Van Auken—General Manager of the Wichita Chamber of Commerce—took the Wichita Weather Bureau to task for creating "unfavorable publicity" and jeopardizing the community's industrial development by using the word 'tornado.' This despite the fact that the warning of 21 June 1948 had undoubtedly saved many lives. The tornado had touched down in a residential area of Wichita and had caused much destruction; however there were no fatalities and only twelve injuries. Even after the Weather Bureau lifted its restriction, the Federal Communications Commission continued to bar television and radio from broadcasting tornado warnings until 1954.[6]

Despite this prohibition, radio—especially in the form of amateur radio—was active in weather and disaster communications. A famous example was the snow and ice storm of 17–19 December 1924 which swept across the Midwestern United States and brought overhead telegraph and telephone lines down. Amateur radio operators provided the emergency communications to replace the incapacitated wired networks.[7]

Radar and computer modeling proved to be the next major advances in the detection and warning of severe weather. In 1946, the Army Signal Corps began modifying surplus World War II gunlaying radars for use in weather detection, and the Weather Bureau commissioned its first weather radar on 14 February 1947. On 25 March 1948, noting a similarity to weather conditions which had spawned a tornado, and tracking an approaching storm on radar, US Air Force Captain Robert Miller and Major Ernest Fawbush made the first official tornado forecast and warning. As weather radar improved, it was able to show tornadoes themselves. On 9 April 1953, Glenn Stout and his colleagues at the Illinois State Water Survey, noticed a distinctive hook-shaped echo on their radar screens and were able to correlate it with a tornado.[8]

In 1971, 10-centimeter pulsed Doppler radars became operational. Doppler radar is able to detect tornadoes even when the hook signature itself is not visible because Doppler radar measures relative wind velocities. However, Doppler radar could not show whether the vortex was aloft or touching the ground. However, seismographs—devices long used for the detection of another kind of natural disaster—were being developed which could detect the vibrations produced by a tornado funnel in contact with the ground.

Seismographs

Luigi Palmieri invented an electric seismograph in 1855.[9] Before this, there had been devices to alert people to the shaking of the earth, for example by balls falling to ring a bell, water spilling. (The author was once shown an Ottoman device using stone columns built into a niche in a mosque in Bursa, Turkey which would rattle audibly in the event of the earth shaking.) Palmieri's device, however, was the first known device which would record the event instead of merely detecting it. His seismograph used cups of mercury which—upon being shaken—would break an electric current to stop a clock to record the time of the earthquake while pendulums and pencil marks on a revolving paper drum recorded the strength of the shaking.[10]

Because electric signals travel faster than the seismic waves through the ground, a J.D. Cooper proposed in a November 1868 newspaper opinion piece that an electrical early-warning system ought to be constructed to warn residents of San Francisco, California of impending earthquakes using seismographs set up in Hollister, California (120 km away). The seismographs were to send an electric signal via telegraph wires, which would have rung a warning bell in City Hall.[11]

An electromagnetic seismograph was invented by Boris Golitsyn in 1906. Tremors from an earthquake moved a coil through a magnetic field, thus producing current. As seismographs developed and increased in sensitivity, the data they collected was used to understand the different movements in an earthquake—the P-waves, the S-waves, and the surface waves—and how they propagated. Later, this knowledge would be the basis of computer models to attempt to understand earthquakes and how the different movements affected the ground, and the buildings standing on them. Computer simulation of earthquakes, and of sea floor displacement likely to produce tsunamis, enabled earthquake-resistant buildings and tsunami barriers to be built.

Tsunami Warnings

The 1 April 1946 earthquake off of the Aleutian Islands in Alaska, U.S.A. and the resulting tsunami led to the creation of the Pacific Tsunami Warning System. In 1949, the Seismic Sea Wave Warning System (SSWWS) was created with its command center in Ewa Beach, Oahu, Hawaii, U.S.A, and the first tsunami warning in Japan was issued on 28 February 1950, after an earthquake under the Sea of Okhotsk.

Initially, tsunami warnings were based on the detection of seismic activity, and whether that activity fit the model of activity likely to produce a tsunami. Real-time mathematical analysis of seismic information was a key proponent of being able to issue earthquake and tsunami warnings. The Pacific Tsunami Warning Center acquired a computer in the 1970s which helped automate the process of locating an earthquake's epicenter and reduce the time between an alarm and sending a message to about an hour. Satellite measurements, which became more available in the 1980s, have also been major advances in the detection and warning of tsunamis.[12]

DART

Since 2003, confirming the existence of an actual tsunami in the ocean has been assisted by DART (Deep-ocean Assessment and Reporting of Tsunami) system, developed by the Pacific Marine Environmental Laboratory. The system consists of a seafloor bottom pressure recorder, and an anchored buoy which provides communications.[13]

Fig.2. A DART Tsunami warning buoy.

The seafloor pressure recorder uses temperature and pressure to detect changes in sea-surface height less than one millimeter in the deep ocean. The seafloor recorder communicates its data with the surface buoy via acoustic transducers, and the surface buoy communicates via two-way radio with Iridium satellites. Backup communications are provided by two independent and redundant systems.[14]

To extend battery life, the pressure recorder operates in normal and event mode. In normal mode, four fifteen-second observations made at fifteen-minute intervals are reported groups of six messages sent hourly.[15] In event mode—which can either be turned on by a radio signal from shore stations, or by two of the 15-second sea-level observations exceeding a pre-set value—data are transmitted for a minimum of three hours. Four minutes of 15-second observations are reported, followed by one-minute averages. Position messages giving the position of the surface buoy are transmitted once per day.[16,17]

Conclusion

The technology of natural disaster warning has become increasingly sophisticated since the 1830s. Yet large loss of life still occurs, and there is still much technology to be developed and deployed.

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About the author

Robert Colburn is the Research Coordinator at the IEEE History Center. He is the author numerous articles and *The Marconi Century*, a history of telecommunications from Marconi's time until the present, which was published by the Marconi Foundation in Italian (*Il Secolo di Marconi*) and in English. In addition to the history of electrical technologies, his historical interests include post-Roman Europe, 15th century Ottoman history, and east-west transfer of knowledge during the Renaissance.

He viewed a tornado close up (about 250 feet) at the age of ten, when it went through the summer camp where he was a camper.

Robert volunteers his time as an assistant high school rowing coach, and competes in rowing regattas at the masters level, having won a bronze and two silver medals at the US Masters Nationals Regatta, and a gold medal at the prestigious international Head of the Charles Regatta in 2001. In the summer of 2000, he was asked to fill in as a spare practice coxswain for the US National Team as it prepared for the Sydney Olympics. In 2006 and 2008, he was a member of the Turkish crew (Fenerbahçe Spor Kulübü).

Robert Colburn

Clarence D. Tuska (1896–1985)

A Centenary Appreciation of a Paradigm Pioneer of Radio

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Abstract

Born in the last years of the 19th Century, Clarence D. Tuska started out as a kid with a coherer at the beginning of the 20th Century, and ended up as RCA's Director of Patents. As a teenager he nurtured the nascent American Radio Relay League as its chief (and only) operating officer. He helped the Army implement the new technology of radio communications. He turned to manufacturing parts and then elegant, now collectable, radios for the burgeoning home market of the "Radio Fad" 1920s. The Superdyne circuit he invented cured a flaw in the vacuum tube circuits of the day. He flourished as an inventor, and wrote often about the creative process of invention. In joining RCA, he joined the cohort of talented radio pioneers that David Sarnoff brought together to manage one of most successful companies of the electrical age.

Inventor Tuska Speaks for Inventors in the Culmination of his Career

Clarence D. Tuska (Figure 1) always hoped that inventors would benefit from their ingenuity. But the big picture also loomed large in his maturity; for example, in 1957 he wrote:

> "Without adequate patent protection it is doubtful if capital would be forthcoming to make further inventions and to develop the inventive things that can continue to do so much for an improved way of life."[1]

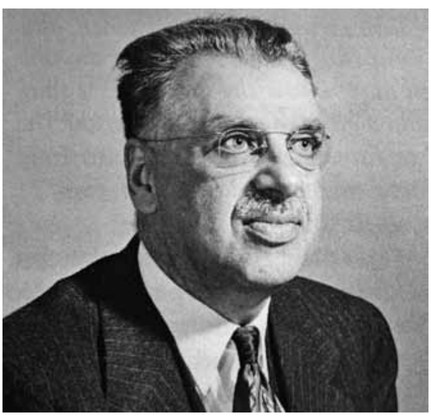


Fig.1. Clarence D. Tuska about 1960 from 1 AWA Review 49.

A summary of one of his books for inventors, a summary likely written by Tuska himself, points to his concern for inventors:

> "What Mr. Tuska's book does is to erect clear warning signals

> along the path which leads from the conception of an invention in the inventor's mind to his ownership of a patent. Properly heeded, these warnings may constitute the difference between acquiring wisdom from bitter experience and acquiring valuable patent rights." [2]

This comment does have a personal ring to it. In the 1950s Tuska also wrote articles for the Franklin Institute encouraging invention and creativity.[3]

Tuska wrote at least four books on invention and inventors, each going into multiple editions, and two popular articles.[4] He had "walked the walk," patenting various sorts of devices. He lucidly explained technical matters. Tuska's inventiveness resulted in unique devices in the new radio field, a company of his own to manufacture them, a novel and clever circuit to improve broadcast radio reception (the Superdyne). He managed the national amateur radio organization as a teenager, and then took a direct commission into the Army to help organize its radio training in the First World War. As a post-war civilian, he rose to the top of the electronics industry of the 20th Century, by managing inventions and inventors.

In the beginning: wireless telegraphy, amateur radio, and the American Radio Relay League

Around 1907, Tuska, as a young boy about 11 years old, got into the wireless game with a metal filings coherer.[5] This he used to detect the signals of the new-fangled wireless telegraphy so well promoted by the likes of Tesla, Marconi, De Forest and Fessenden, and much used by the Navy. Tuska had first experimented with his metal filings coherer detector. Within three years he had graduated to a spark coil transmitter (albeit untuned), two antennas configured as dipoles, and for his receiver, a tuning coil with two slides. An electrolytic detector from Hugo Gernsback's E.I. Importing Company "… did not operate at all well …" so he moved on to a crystal detector. Next came a loose coupler, and a pair of headphones,[6] top-of-the-line Brandes. Working at this technical level, he and Hiram Percy Maxim met about 1910.

The amateur experimenters joined the professional communicators in exploring the possibilities of the novel medium of wireless telegraphy. The relatively low transmitting power available to the amateurs put a premium on experiment and cooperation. The high power commercial, maritime and Navy installations always made for a plethora of signals to hear, some very interesting indeed. Then in 1912, after probably justified claims of some amateurs interfering with Navy and commercial traffic, the U.S. Government exiled the amateurs to wireless Siberia, to wavelengths of "200 meters and down"[7] (*i.e.*, 1500 KHz and up). So some folded their antennas. Many amateurs took this restriction to be merely advisory with no enforcement until 1916, thus keeping amateur radio more alive than the law's sponsors intended. (This was to prove in the national interest in World War One.) Others, however, such as Tuska and his Hartford, Connecticut neighbor, businessman Maxim, persevered and within the law. They laid a foundation ultimately to worldwide, low power, frequency agile, multi-mode communications as public service as well as an engaging technical and social hobby.[8] Their work resulted in the American Radio Relay League in 1914.[9]

As was often an American trait of that last century, high school student Tuska wanted to make some money for himself. Tuska had made money by offering toy airplanes, and various wireless components, of his own design and manufacture, on consignment at a local toy store. He likely made them on his kitchen table. He put together a wireless receiver and offered it in the toy store. Maxim's son had an interest in wireless. At the toy store, Maxim saw and bought Tuska's receiver for his son. But Tuska found out that Maxim had returned it to the store. This occasioned some discussion in the Tuska home, likely at that kitchen table.

In a later reflection, Tuska remarked, with respect to his mother, "During most of my youth, she had to be both father and mother." So she insisted: go call on Mr. Maxim to ask why he'd brought the receiver back. A boy with gumption, he did just that. It turned out that there was nothing wrong with Tuska's construction. Maxim, however, had some knowledge of the new wireless enthusiasm. A more professional set was more to his liking. Tuska reached for state of the amateur art, and built one for Maxim, probably much like his own. The Maxim family and Tuska soon communicated by wireless telegraphy with the self-assigned callsigns of SNY, SNW, and for Tuska, SNT. The elder Maxim and Tuska soon developed '… a friendship … more of a father-foster-son relationship."[10] Maxim later urged Tuska to go to college and facilitated his entry into Hartford's Trinity College.

Maxim, with the collaboration of "… that brilliant Hartford youth, Clarence D. Tuska, launched our League …"[11] (ARRL) in 1914, one hundred years ago. Tuska, about fourteen years old, had just started high school in Hartford; Maxim was a more than forty -year -old successful businessman and inventor. Maxim was the older, wiser partner, and instigator in the novel organization. He was, in fact, "The Old Man" of early American Radio Relay League *QST* magazine commentary, for example "Rotten QRM." Just a "young squirt," (see Figure 2) Tuska worked in the attic of his home and nonetheless became ARRL's Secretary and most devoted officer.[12] He and Maxim founded *QST* privately in 1915. They also incorporated the League in 1915, along with their lawyer. The ARRL's incorporation permitted it to protect its ideas and operations, even as a non-profit entity.

Tuska came to own *QST* although the League assumed its operations in 1919, paying off Tuska's associated but personal *QST* debts with a bond issue.[13] Tuska handled the organization of ARRL in 1914 but Maxim announced its formation as a relay league of amateur

Fig.2. Tuska about 1915, ARRL photo. Maxim's son, Hiram Hamilton, remarked on Tuska's striking green eyes. Immigration records suggest that most Tuska families came out of Eastern Europe, mostly Hungary.

wireless operators.[14] The then short range and low power of amateur stations limited them in terms of distance, but those very characteristics thereby created an opportunity to link nearby amateurs in all directions in order to relay messages longer distances.

"It may be that we have in this idea a great organization in the making" Maxim, a man of vision, noted at the time. The relay concept, already in use by other services, not only passed traffic, but it also linked amateur wireless men regionally and soon nationally. ARRL relay stations were licensed at a special wavelength, 425 meters,[15] about 700 KHz. These were the days of spark sets capable of maybe a 30-mile range, at best a little more. Yet other ways of communicating faced limitations of their own. U.S. Mail could take a long time before airmail service. For telegrams, Western Union charged a monopoly price, limiting use mostly to businesses. Telephones were few and far between, and used primarily for local business. Long-distance telephone service had to await the coming of vacuum tube amplifiers in the 1920s.

Maxim and Tuska knew that enthusiastic amateur wireless operators lived everywhere in the country, as was shown by a number of publications. An amateur radio message relay network, they realized, could meet a demand for conveying personal messages, perhaps even across the continent (as it soon did, in January 1917).[16] Moreover, the price was right: free. This network could thus demonstrate an important virtue of amateur wireless. It could and did also show the promise of rapidly evolving amateur radio. But as Maxim and Tuska foresaw, just handling the traffic would bind together amateurs around the country. The events of 1912 had shown that amateur radio had faced an existential risk; other such risks could (and would) be in the offing.

In his history of ARRL, Clinton B. DeSoto, writing "Two Hundred Meters and Down" in 1936 points out that in this period after 1912 amateur wireless evolved from primarily experimentation to primarily communication.[17] The many wireless and radio publications of the day facilitated experimentation. Yet the attempted organizations of amateurs did not flourish. These groups did not have as a purpose inter-communication in the ether among their members, but that is exactly what Maxim, Tuska and ARRL accomplished with the notion of amateur relay traffic. ARRL knit a nationwide social fabric with the strength to muster thousands for First World War service,[18] later in defense of amateur radio itself, and in the ensuing decades in emergency service and national defense.

Clarence Tuska as a young man devoted several years to ARRL and edited its magazine *QST*, and defended amateur radio after the First World War. He held several radio licenses from the U.S. Department of Commerce: 1AY, 1WD, 1ZT (a special class) as of 1915, and later 1XV, experimental class, 1920–'21.[19] (Maxim held at least two callsigns before his final call W1AW.[20])

In 1915, the Institute of Radio Engineers made Tuska a member, a signal honor for an amateur.[21] At the time, Major Edwin Howard Armstrong's new regenerative circuit and its "oscillating Audion" vacuum tube heart had captured the imagination of the radio world. Tuska explained it to amateurs in an article for *QST* in 1916.[22] With this one-tube regenerative receiver Tuska copied Honolulu from Connecticut.

Tuska Anticipates—and Practices—Broadcasting

David Sarnoff at R.C.A. later claimed that he thought up the "Radio Music Box" for the home in 1916.[23] Maybe so, maybe not, but Tuska as early as 1916 grasped the power of oscillating vacuum tubes to broadcast speech and music by modulated continuous waves. So he did it:

> "It was not long before I had a 50-watt oscillator and a 50-watt modulator in operation. I was able to transmit understandable speech and music of passable quality over a normal radius of 25 miles. It was a common occurrence for other amateurs to ask me to transmit music for visitors… Regular broadcasting, as we know it today, had not started. I foresaw a real future for paid broadcasting because I knew that the audience was starting to grow."[24]

A photo of Tuska at his radiophone (Figure 3) appeared in *Wireless Age* magazine in February 1917.[25] Like Lee de Forest and Charles D. "Doc" Herrold, among others, Tuska helped to invent broadcasting before the post-World War One technology advances made it a household amenity.

Tuska Serves in the War to End All Wars

In early 1917 war loomed. *QST* editor Tuska wanted to play his part:

> "By the end of July, QST had just about run out of money and had about used up its credit, and its Editor and factotum wanted a more active part in the War

Fig.3. Tuska at his broadcasting radio-telephone station circa 1916–'17, from *Wireless Age*, February 1917 at 352. Note the spherical audion to the left, and the large inductance at the top right, and a bank of vacuum tubes at the bottom of the transmitter on the right. The original caption notes. "… By making his victrola a part of his transmitter he has been giving wireless concerts for the benefit of amateurs in and about Hartford…."

> effort. QST was put to bed, and its editor left for Washington."[26]

In the Great War, Lieutenant Tuska, with outstanding recommendations, served in the Signal Corps, a natural fit. He directed a radio school as Officer in Charge and served in two other assignments as a Radio Officer.[27] In the first volume of the AWA Review, he told of his wartime experience.[28]

His first assignment as a new Signal Corps officer was to establish a radio school in Texas. He served there with an experienced commercial operator and early (1910) aviator, Elmo N. Pickerill. Figure 4. A little later Tuska met K.B. (Kenneth) Warner, who so impressed Tuska that he talked Warner into taking over *QST* and as Secretary of ARRL after the war ended and amateur radio could once again take to the ether in 1919.[29]

Like Tuska, "… [d]ozens of the more competent amateurs were taken directly from private life and given commissions on the strength of their amateur proficiency" according to ARRL.[30] Tuska's bailiwick was to organize radio training in the Air Service. Tuska wrote, near to the events:

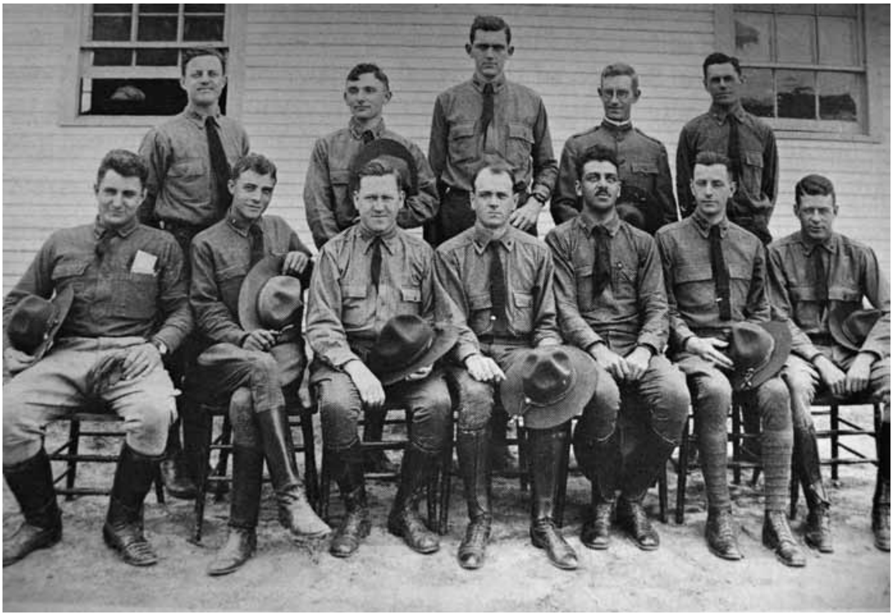


Fig.4. Tuska's Texas Air Service radio class; he is third from right, looking well tanned, and Elmo Pickerill is to his right. From 1 AWA Review.

> "The amateurs have come across in the case of the Army. … I have turned out a whole lot of operators for the Air Service and have become pretty well acquainted with the type of human it takes to make a first-class radio operator… The very first sort of student we looked for is an ex-Amateur. He seems to have had all the experience and all we have to do is acquaint him with a few special facts and he is ready for his Army job. They've surely done their bit and I am mighty proud I was one."[31]

In Tuska's Aviation Section, the SCR 65 with its BC-15A spark set flew in the spotter aircraft. Figure 5. On the ground, the SCR 54 with its BC 14 receiver and VT-1 vacuum tube detector received the signals from the aircraft. Figure 6. Tuska explained the process:

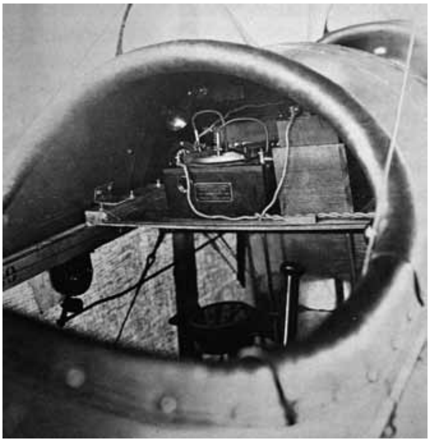


Fig.5. The SCR 65 airborne spark set. From 1 AWA Review.

Fig.6. The SCR 54 ground receiver. From 1 AWA Review.

> "Returning to the 1918 apparatus: its principal purpose was to send signals from an airplane to a ground station to direct artillery fire. The ground station signaled an observer in the airplane by a visual code … Generally the plane was flown toward the artillery battery, radioing the battery to fire just as the plane made a turn toward the target. An the observer in the plane watched for the shells to burst around the target; then the plane was turned promptly toward the battery, indicating if the shells fell long or short, and about how far off target. The necessary gun correction having been made, the progress continued until the target was hit. A well-trained crew with good teamwork was a must. We simulated battlefield conditions and trained men to install equipment and operate under abnormal conditions, such as bad interference, weak or fading signals, faulty gear, and to quickly make any necessary adjustments or repairs"[32]

Marconi himself, Chief of Signals for the allied Italian Army, praised the amateurs of the sort Tuska worked with in the U.S. Army and at ARRL:

> "America is fortunate in having perfected its organization in the amateur field…. American Wireless men are exceptionally

well qualified to take an active part in important signaling work."[33]

The Siren Call of Commerce and Invention

Out of the Army after the Armistice, it was time for Lt. Tuska to make his own way, and to make a living for himself. The exploding radio field in 1919, which he had foreseen, called him to commerce. True to his personal ethics, "… by reason of commercial connections, since he was entering the radio manufacturing business"[34] Tuska resigned as ARRL Secretary at a meeting on March 16, 1919.

In June 1919, he spoke for ARRL before a U.S. Senate Committee in testimony objecting to a proposed U.S. Navy takeover of the airwaves. [35] He was at most 24 years old at the time. Maxim had made prior Washington appearances on behalf of the League. Tuska's Senate testimony shows Maxim's continuing confidence in him.

At the time, the local A.C. Gilbert Company of Hartford made all sorts of toys and things of interest to young men. Tuska went to work for it as "designing engineer," promoted its crystal sets and radio supplies, and wrote an article for the company entitled: *The General Theory of Wireless Telegraphy*.[36] Next he made similar crystal sets[37] as his own radio parts company.

Tuska elected to forego radio broadcasting, despite holding the commercial land station license WQB as of September 1921, perhaps in connection with A.C. Gilbert. [38] He did, however, form "The C.D. Tuska Company [of] Hartford, Conn." initially to make radio apparatus of his own design. In mid-1919 Tuska placed a signed advertisement[39] in *QST* for "Radio Instruments at Amateur Prices" saying: "Our Aim: To sell good but inexpensive apparatus." Figure 7. His product line soon filled out,[40] including a coaxial tubular variable condenser he invented. In November 1919 he advertised[41] his "New Hi-Volt Storage Battery"—24 volts and built-in recharger from the AC mains.

Tuska Creates the Elegant *Superdyne* of the 1920s

The regenerative detectors of the receivers of the early 1920s earned themselves the sobriquet "bloopers" because their radiated squealing interfered with other sets. This much annoyed the neighbors. Several designers isolated the detector from the antenna with a radio frequency amplifier ahead of it. Stray capacitances in the triodes of the day nonetheless enabled a sort of

Fig.7. Tuska's signed July & September 1919 *QST* advertisement.

regeneration in radio frequency amplifiers. This was especially so in high-gain, multi-stage tuned radio frequency circuits (TRFs). The sets all too often defaulted to squealing oscillation.

The TRF circuit could provide outstanding sensitivity because, as Tuska wrote, the tuned radio frequency stages

> "… amplify the radio frequency before it gets to the detector. If this can be done, it is very much worthwhile because the response of the detector increases approximately as the square of the voltage applied to the grid."[42]

Tuska's briefly well-known Superdyne (Figure 8) circuit solved the problem (the "dyne" suffix for so many early circuits comes from the Greek word for power or force). He made and sold, nationally, several models of broadcast receivers for the home, between 1922 and 1925.[43] The first editor of this AWA Review, Robert M. Morris, wrote: "The Tuska Co. … designed and produced some excellent radio receivers, now prized in any collection of early radio equipment."[44]

As his 1916 article had shown, Tuska thoroughly understood Armstrong's regenerative circuit that used inductive positive feedback to enhance receiver sensitivity. But it was too much unintentional and unregulated capacitive feedback that caused the squeals and whistles. The process of invention ne'r runs smooth:

Fig.8. The C.D. Tuska Company Superdyne, circa 1924. From the Steve Johannessen (AWA) collection, his photo.

> "It was evident that we *must* use resonant circuits and it was further apparent that the minute we did use resonant circuits, the tubes would start to oscillate and spoil everything."[45]

Tuska solved the problem with an inventor's insight: use negative inductive feedback to stabilize the circuits:[46] "All that is necessary is to put in the conventional Armstrong feedback *but to feed the energy back in the reverse direction or negatively.*" (Tuska's emphasis; see Figures 9 & 10). He coupled a coil from the plate to the grid in opposite polarity. Figure 11. This inductive negative feedback canceled the stray capacity positive feedback if adjusted carefully by rotation. However, if adjusted even more delicately, some residual-capacity positive regenerative feedback remained. This provided " … astounding degrees of amplification" wrote Tuska.

Tuska had managed the technical problem of the triodes of the day. (See Figure 12, the Tuska Company logo). He took advantage of the necessary adjustment to make it his sets' volume

Fig.9. A triptych of the Superdyne with details of Tuska's patent application no. 807,388 at the right. From the Steve Johannessen (AWA) collection, his photo. This appears to be a model 305. Radiomuseum.org notes additional Superdyne models. 228, 301, & Superdyne Jr., and there may have been other models.

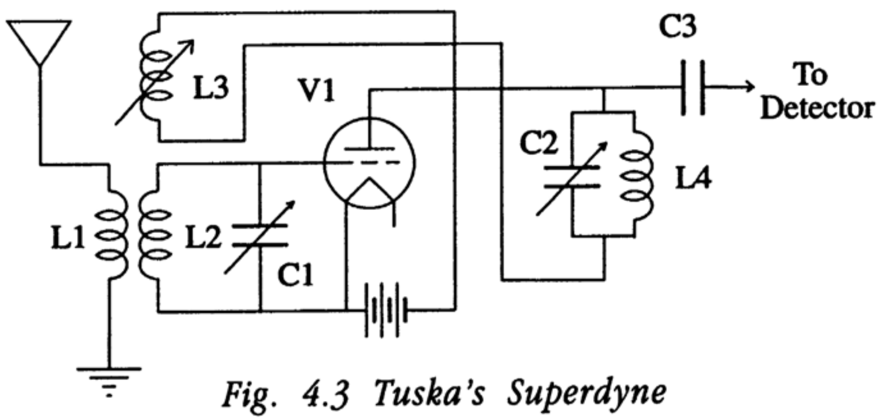


Fig.10. A schematic diagram of the Superdyne circuit, from David Rutland, Behind The Front Panel, *supra* n. 46 his Fig.4.3 at 35.

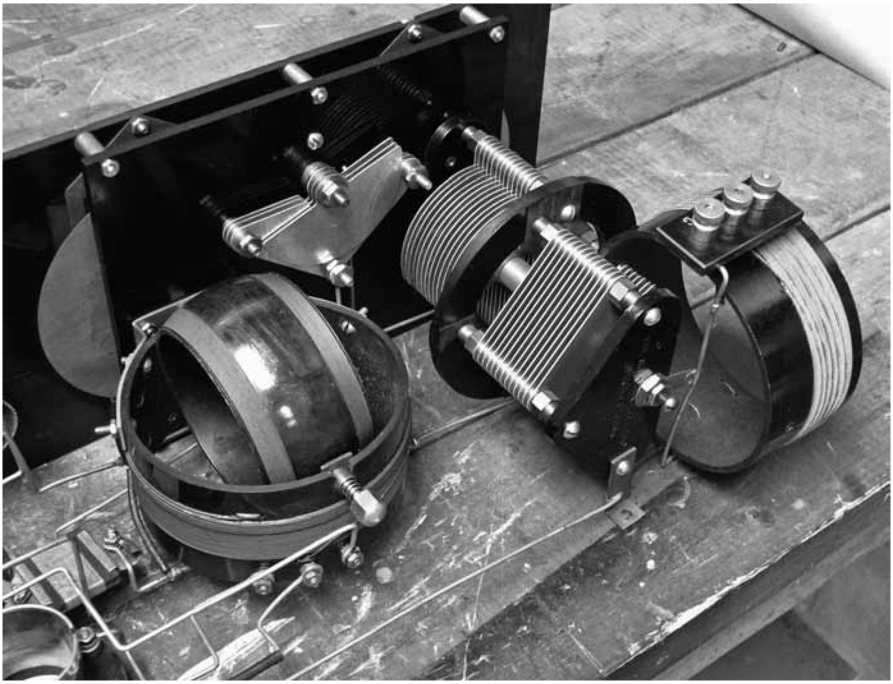


Fig.11. The adjustable inductive negative feedback device in the Superdyne. From the Steve Johannessen (AWA) collection, his photo.

Fig.12. The Tuska Company logo (a detail from an AWA photo).

control. But the adjustments, alas, tended to require more than consumer level skill and dedication, because retuning to a new frequency required readjustment of the feedback. Judging from the newspapers of the day, most listeners, at least during the day, were women who were not technically inclined. Only hobbyists wanted to fool with the knobs. (In general, people just wanted to turn their radios on, tune them in to a nearby station, and turn up the volume, while doing housework during the day, relaxing at night, or partying on the weekends at home during Prohibition, to the music of the local hotel orchestra.)

The Superdyne circuit soon fell to the capacitive neutralization of Professor L.A. Hazeltine.[47] This Neutrodyne circuit required no adjustment because it used factory installed insulated wires in a small cylinder to provide the needed counter-capacity, the "Neutrodon" condenser. In due course, a quite short course, the Neutrodyne in turn bowed to the screen grid tube, the tetrode. Its second grid eliminated the capacitive feedback that haunted triodes. The popularity of Armstrong's Superheterodyne circuit soon followed, as did pentodes. This stable universal circuit dominated for decades until the advent of direct heterodyne detection in software defined radios—a reversion to Fessenden's original circuit.

After his own run at radio manufacturing, Tuska took his technical and commercial experience to Atwater Kent.[48] This company is now famous for its 1920s multi-dial breadboard receivers. The company made them to look like laboratory equipment as a marketing ploy. Atwater Kent soon moved on to the familiar metal boxes that were so much easier to operate.[49]

RCA Gets the Inventors' Inventor

In the midst of the Depression (1935), Tuska moved on to R.C.A.'s patent department,[50] as one of David Sarnoff's pool of talented executives who had individually pioneered radio in its earliest days, two decades or more before. R.C.A's distinguished hires included Elmer T. Cunningham, Arthur I. Isbell, Harold Beverage, and Elmo Pickerill, as well as Tuska. A high federal court in 1956 called Tuska "R.C.A.'s patent lawyer."

The court's opinion in that case provides insight into the operations—and challenges—of a busy industrial patent department.[51] With respect to the wartime RADAR patent at issue, the court noted:

> "There was considerable delay in filing the application for [this RADAR] patent. This is explained by R.C.A.'s patent lawyer, Mr. Clarence D. Tuska, by the fact that there were many applications in this general field to be made by him and they could not all be made simultaneously.... The veil of secrecy had been put over the results of experiments in the radar field for reasons of national security."

Tuska himself patented a wartime improvement to radio direction finding in 1942,[52] and continued to invent for several more years. [53]

Tuska did not train as a lawyer and did not practice law, but he did the work of senior patent counsel. He long acted as Director of Patent Operations at the R.C.A. Laboratories in Princeton, New Jersey. Tuska also continued to write prolifically on patents.[54]

Conclusion

Clarence D. Tuska enjoyed many adventures in early wireless telegraphy, in the early days of ARRL, in the Army, and in invention and commerce. His varied experience made Tuska a sympathetic and effective manager of electronics engineers and inventors. His reputation as a manager and a man was outstanding. His books about inventions and inventing, written in a down-to-earth tone and approach, encouraged inventors and honored the creative process. They are deeply historical and humane, with references to objects of art as well as technical matters.

Clarence D. Tuska was born in 1896 and died in 1985. This brilliant youth of 1914 advanced for his whole life one of the leading technologies of the 20th Century.[55]

Endnotes

1. C.D. Tuska, Inventors and Inventions (New York, 1957—hereinafter sometimes Inventors), Preface at vi.
2. This quote comes from the advertisement for his Patent Notes For Engineers (R.C.A., 1947) at the back inner dust jacket of his An Introduction To Patents For Inventors And Engineers (1957).
3. C.D. Tuska, *So You Want to be an Inventor*, Journal of the Franklin Institute, Vol. 255, No. 3, pp. 177–188 (March 1953); *Increasing Inventive Creativeness*, Vol. 260, No. 2, pp. 93–98 (August 1955).
4. Patent Notes For Engineers (R.C.A., 1947, multiple editions at RCA); Inventors and Inventions (New York, 1957); An Introduction To Patents For Inventors And Engineers (seven editions through 1964); and at age 76, Patents, And How To Get One For An Invention, two editions, 1972. His articles on invention are cited in the note above.
5. CellStream History of Telecommunication Timeline Wiki, http://www.cellstream.com/wiki/1900-1910, for 1907.
6. C.D. Tuska, *A Memorable Meeting* [with Maxim] in Fifty Years of ARRL, ARRL (Newington, 1965) at 5. Much of Fifty Years is attributed text from DeSoto, Clinton B., 200 Meters and Down, *supra*.
7. See generally, Clinton B. DeSoto, 200 Meters and Down (ARRL, Newington, CT, 1936 and reprinted).
8. The International Telecommunications Union (ITU) and the U.S. Federal Communications Commission define amateur radio:

   "A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is by duly authorized persons interested in radio technique solely with a personal aim and without a pecuniary interest" (ITU Regulations, Section III Radio services 1.56 amateur service; F.C.C. Regulations, C.F.R. Part 97 at 97.3(a)(4)).
9. ARRL, The National Association for Amateur Radio® celebrates its 100 year anniversary in 2014, in part by a series of historical articles in its magazine, *QST*. These articles include: Michael Marinaro, *In the Beginning*, *QST*, January 2014 at 69; Chris Codella, *Hiram Percy Maxim*, *QST*, February 2014 at 72; and Lee, [working title] *Clarence D. Tuska, Radio Pioneer, ARRL Founder*, [forthcoming] 2014. (This last is an earlier approach to some of the story of the present article). *QST* has been the primary publication of ARRL since 1915.
10. *A Memorable Meeting* at 5-6. Before 1912, amateurs selected their callsigns for themselves, often with some local cooperation among themselves.
11. *QST*, April 1936, in Fifty Years.
12. Fifty Years at 15.
13. Fifty Years at 26. League members raised money by bonds to pay off the debt that Tuska had taken on to publish *QST*. Some kept the bonds uncashed as souvenirs thereby making donations to the cause.
14. *Electrical World*, May 9, 1914 at 1057. Maxim seems to have avoided the publications of Hugo Gernsback (*e.g.*, *Modern Electrics*) who had sponsored the Wireless Association of America in 1909, which Gernsback could have seen as a rival to the nascent ARRL.
15. Fifty Years at 14; De Soto, *supra* at 41:

Maxim went to Washington in 1914 to get authorization for the special wavelength longer than 200 meters.

16. DeSoto, 200 Meters and Down, *supra* at 49. A message from the Seefred brothers, station 6AE in Los Angeles, reached Maxim and Tuska in Hartford at 1ZM by relay of half a dozen stations. By 1933, amateur radio handled 1.5 million messages, "20 per cent. of which were for the general public." *Ibid.* at 180; that comes to 300,000 free messages transmitted for a public suffering the financial stresses of the Depression. At today's postcard rate of 34 cents, that comes to something over $100,000; telegrams would be at least ten times more costly.
17. DeSoto, 200 Meters and Down, *supra* at 37 & 174.
18. *Ibid.* at 54.
19. Radio Service Bulletin, Bureau of Navigation, Department of Commerce, reports in issues 5 and 42, May 1915 and October 1920, and Fifty Years at 5 for 1WD; other sources as well, not all of which are consistent as to old call letters.
20. *QST*, April 1936 in Fifty Years; these included 1WH and later the special call 1ZM. (Perhaps "M" for Maxim by the courtesy of a friendly Radio Inspector, inasmuch as Tuska held 1ZT assigned at the same time).
21. His membership in the Institute of Radio Engineers as of 1915 is noted in his *QST* article *Pictured Electro-Magnetic Waves*, (December 1915) Issue No. 1 at 9.
22. *QST*, January 1916, accessible at http://en.wikisource.org/wiki/QST/January_1916/ The_Oscillating_Audion.
23. See, *e.g.*, Radio's First Two Decades at 49 (1987) reprinting part of Radio From Start to Finish (1942); Gleason L. Archer, History of Radio to 1926, at 112–113 & 189 (reprint Arno, 1971). But the first record of the suggestion is 1920; see, *e.g.*, Tom Lewis, Empire of the Air at 149 (1991).
24. C.D. Tuska, Inventors at 118–19.
25. See nearby photo from *Wireless Age*, February 1917 at 352.
26. C.D. Tuska, *A Radio Amateur in World War I*, 1 AWA Review 49 (1986).
27. *QST*, June 1919, the "Re-Opening Number" of *QST* at "Personal Notes." Official records note his service at Camp McClellan, Alabama, his last duty station. Annual Reports of the War Department, Vol. 1, Part 4 (1918) at 5170 (accessible on Google Books).
28. Tuska, *A Radio Amateur in World War I, supra*.
29. *QST*, July 1919 at 14.
30. DeSoto, Two Hundred Meters and Down, *supra* at 53.
31. *Ibid.* at 53 quoting Tuska.
32. C.D. Tuska, *A Radio Amateur in World War I, supra* at 56. Along with radio adventures, Tuska, serving in the Aviation Section of the Signal Corps, enjoyed all the drama of early aircraft, including involvement in crashes, getting lost flying at night, fuel leaks in the air, and more.
33. DeSoto, Two Hundred Meters and Down, *supra* at 53
34. Fifty Years at 26; ARRL has no letter of resignation on file.
35. Use of Naval Radio Stations for Commercial Purposes: Hearings… September 4, 1919 (U.S. G. P. O., 1919) at 95 (accessible on Google Books).
36. *QST*, June 1919 at 22 "Personal Notes";

also noted in Maurice L. Sievers, Crystal Clear: Vintage Crystal Sets, … Vol. 1 at 35. A 1920 A.C. Gilbert company pamphlet contains the article by Tuska on *The General Theory of Wireless Telegraphy*: A.C. Gilbert Company, Boy Engineering (Hartford, 1920) at 31.

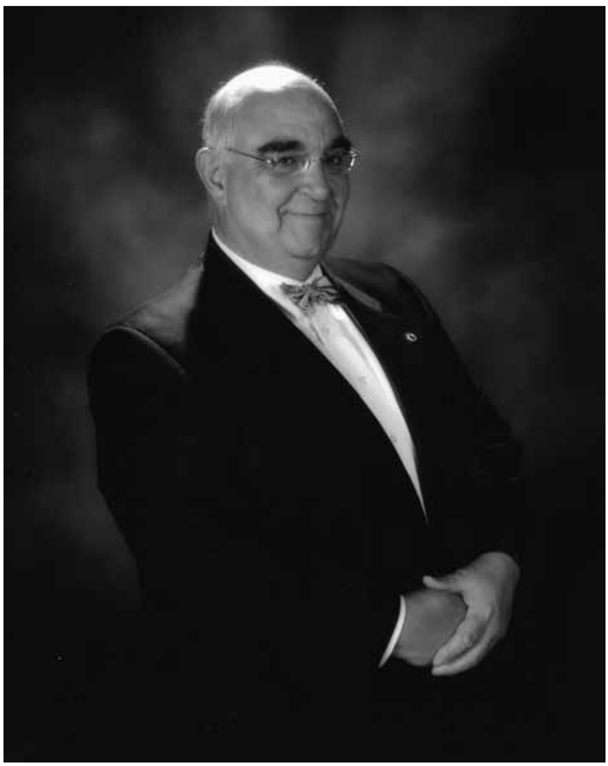
37. *E.g.*, Tuska model No. 4007; Crystal Clear at 35.
38. Ed Brouder of Hartford radio station WDRC, www.wdrcobg.com/ acgilbert3.html.
39. This advertisement appeared in *QST* in July 1919 at 25.
40. See, *e.g.*, C.D. Tuska Company, Experimental Radio Apparatus, Catalog No. 1 (Hartford, n.d. *circa* 1920 [reprint]) and *QST*, August & September 1919 at 25 & 38 respectively. In March of 1919 he had patented the coaxial tubular variable condenser, U. S. Patent 1,371,061, reported in *Electrical World* (1919, Vol. 77), reissued Sept. 23, 1923, No. Re.15689. This device would appear to be the Variable Condenser pictured in Tuska's 1919 *QST* advertisement.
41. *QST,* November 1919 at 51.
42. C.D. Tuska, *The Superdyne Receiver*, *QST*, November 1923, at 7–12.
43. Much information on Tuska's radios, and thousands of others may be found on Ernst Erb's www.radiomuseum.org, *e.g.*, search "Tuska."
44. Robert M. Morris, W2LV, in his Editor's Note to C.D. Tuska, *supra*, 1 AWA Review at 63. Morris inserted the Tuska Company battery advertisement at the end of his note at 64 his Figure 10.
45. Tuska, *The Superdyne Receiver*, *supra*.
46. This analysis comes from David Rutland, Behind The Front Panel—The Design & Development of 1920's Radios, (self-published 1994; reprinted by permission by the California Historical Radio Society in 2014) at 33ff, relying on C.D. Tuska, *The Superdyne Receiver*, *supra*.
47. See Mike Molnar, *Hazeltine, the Neutrodyne and the Hazeltine Corporation*, 26 AWA Review (2013) at 3, 9ff and its Figure 7. See also, Rutland, *supra* at 36ff and its plate 13.
48. He assigned a refrigeration patent to Atwater Kent as late as 1934: U.S. Patent 2,042,568, filed Sept. 29, 1934.
49. Ralph O. Williams, *The Atwater Kent Radios*, 12 AWA Review 5, 283–285 & 305–306, declares that radio design at the Atwater Kent company had become "hum-drum" by 1934–'35 and the company turned to refrigeration, but Atwater Kent closed it in 1936.
50. He assigned his patent on his Superdyne system, filed in 1923, but granted in 1933, to RCA: U.S. Patent 1,925,291A. This patent discusses in detail Tuska's solution to the neutralization problem. It is a fair inference that assignment of this patent related to his employment in 1935.
51. *Radio Corporation of America et al., vs. International Standard Electric Corporation*, 232 F. 2d 726, 731 (3rd Cir., 1956).
52. U.S. Patent 2,279,021, April 4, 1942.
53. In addition to the Superdyne patent, Tuska enjoyed at least six other patents dating from 1922 to 1969, according to Google patents.
54. *E.g.*, C.D. Tuska, Inventors and Inventions, *supra,* (New York, 1957; nine editions) at inner dust jacket biography. Tuska also wrote Patent Notes For Engineers for R.C.A. in 1947, which went through 22 editions. See notes 2–4 *supra.*

55. His son, James D. Tuska, continued the family tradition as an inventor for RCA; he died in 2013: http://www.seacoastonline.com/articles/[*etc.*]. Clarence Tuska's grandfather Morris immigrated from Hungary (1844) and was prominent in the New York Jewish Community, after working the California Gold Rush. He died in 1903. Tuska's father David died in 1909. Tuska was born on August 15, 1896 and died on July 1, 1985.

About the Author

Bartholomew (Bart) Lee, K6VK, xKV6LEE, WPE2DLT, is a long time member of AWA and a Fellow of the California Historical Radio Society (CHRS), for whom he serves as General Counsel Emeritus and Archivist.

He has enjoyed radio and radio-related activities in many parts of the world, most recently in East Africa. Radio technology and history have fascinated him since he made his first crystal set with a razor blade and pencil lead more than 50 years ago. He is especially fond of those sets of which it is said: 'Real Radios Glow in the Dark.' Bart is a published author on legal subjects and most recently on the history of radio. He has written about and lectured on early radio technology, radio intelligence activities ('episodes in the ether wars') from 1901 into the latter 20th Century, wireless telegraphy especially Marconi's early work, wireless developments on the West Coast since 1899, radio ephemera including radio stamps, and radio in emergency and disaster response. Since 1989 he has made some 20 presentations to the AWA conferences on his research interests including short wave radio and the development of television in San Francisco in the 1920s. The AWA presented its Houck



Bart Lee. Photo by Paula Carmody taken in Indonesia; copyright Bart Lee 2009.

Award for documentation to him in 2003 and CHRS made its 1991 'Doc' Herrold Award to him in connection with his work for the Perham Foundation Electronics Museum. In 2001, during disaster recovery operations in New York after the '9/11' terrorist enormity, he served as the Red Cross deputy communications lead from September 12 to September 21, (the 'night shift trick chief'). He has served in RACES as the Liaison Officer for the San Francisco Auxiliary Communications System, and as an ARRL ARES Emergency Coordinator.

He presently serves as an ARRL Government Liaison and Volunteer Counsel, and holds an FCC Commercial licence (General with RADAR) as well as an Amateur Extra Class licence. Bart has been a litigator by trade, prosecuting and defending civil cases in both state and federal court for 40 years. He also had taught Law & Economics for 20 years, including the economic history of telecommunications.

He is a graduate of St. John's College (the 'Great Books School') and the University of Chicago Law School.

Bart's son Christoffer Lee is also a licensed amateur radio operator and is now also a practicing lawyer. Bart invites correspondence at: KV6LEE@gmail.com .

The 5-T Hallicrafters Sky Buddy and All Other Sky Buddy Models

Abstract

Although Hallicrafters made innumerable radios and other electronic products over many years, the Sky Buddy stands out as an early and important series highly prized by collectors. The fact that the first Sky Buddy, the 5-T, had a boy depicted on the celluloid dial is especially intriguing and attractive to collectors. If one includes the Sky Buddy II, the Sky Buddy name lasted over 25 years. This article includes information on restoration of the 5-T Sky Buddy tuning mechanism and comparative information on the 5-T, S-19, S-19R, and S-119 receivers, thus the entire Sky Buddy series.

Introduction

This article will cover both versions of the Hallicrafters famous 5-T Sky Buddy, and the other Hallicrafters models using the Sky Buddy name: the S-19, the S-19R, and the S-119. The dial face of the earliest 5-T Sky Buddy is unusual as it pictures a boy wearing headphones. On the later 5-T models, there is no boy. Throughout this article, to distinguish the two variations, the terms "5-T With Boy" and "5-T Without Boy" will be used.

At the outset, the name Hallicrafters has been revered by the amateur radio community since the late 1920s, by the military, especially during WWII, and by radio enthusiasts everywhere. In his wonderful books, Chuck Dachis (Ref. 1, p. 8–9), has presented a history of Hallicrafters that need not be repeated here. Suffice it to say that the work of Chuck Dachis and an earlier book by Max de Henseler (Ref. 2) cover much of what is known about Hallicrafters. The excellent details on radio restoration by Chuck Dachis (Ref. 1, p. 19–20) are really great concepts for the restorer. Chuck has stated that "I will sometimes purchase as many as five radios of the same or similar model to get enough parts to restore one" (Ref. 1, p. 19). In the case of the 5-T Sky Buddy, I have certainly found that to be the case. Several sets had good parts made but extra holes in the panel for send/receive switches, magic eye tuner tubes, pilot lights and the like. One of the most daunting aspects of the restoration of the 5-T Sky Buddy was to replace the belt-type tuning cable buried in the mechanism. I have found that this is the most difficult compared to circuit problems. A special section in this article covers that issue. Surprisingly, the proper cable can still be found, occasionally, on eBay. Another important area is the differences, other than the dial, between the 5-T With Boy and the 5-T Without Boy. For completeness, the rest of the Sky Buddy series, the S-19, the S-19R, and the S-119 Sky Buddy II will also be covered.

The Hallicrafters 5-T Sky Buddy With and Without Boy

The initial production run of 5-T Sky Buddy (1935–1936) had a dial showing a boy sitting at a desk wearing headphones with his right hand on a telegraph key (Fig. 1). This was artwork incorporated into the celluloid dial. The name Sky Buddy appeared only in the upper left hand corner of the radio's front panel. According to Chuck Dachis (Ref. 1, p. 21), legend has it that Bill Halligans' neighbor had a youngster, Buddy, who was a radio enthusiast unable to afford an expensive commercial set. Bill had an introductory radio priced at $29.50 made and called it the Sky Buddy in the boy's honor. Since Hallicrafters did not have a license to use RCA patents at the time, it is felt that the production of the Sky Buddy With Boy was made by the Howard Radio Company, which did have such a license (Ref. 1, p. 21).

According to the Sky Buddy Model 5-T Operating Instructions, the three band receiver frequencies are:

No. 1 Band – 545 KHz to 1680 KHz
No. 2 Band – 1680 KHz to 5.5 MHz
No. 3 Band – 5.5 MHz to 16 MHz.

Since the next version (1936–1937) of the 5-T used a different tuning mechanism and had changes in the dial, it suggests that they were made entirely by the Hallicrafters and not Howard,

Fig.1. Hallicrafters 5-T Sky Buddy With Boy.

and sold at the same price of $29.50. It was available "on-time" at $2.50 per month. These had the boy replaced by a more colorful dial with the words "SKY BUDDY by the Hallicrafters" (Fig. 2). As far as I can tell, the schematic (Fig. 3) but not all the components such as the tuning unit, are the same.

Fig. 2. Hallicrafters 5-T Sky Buddy Without Boy.

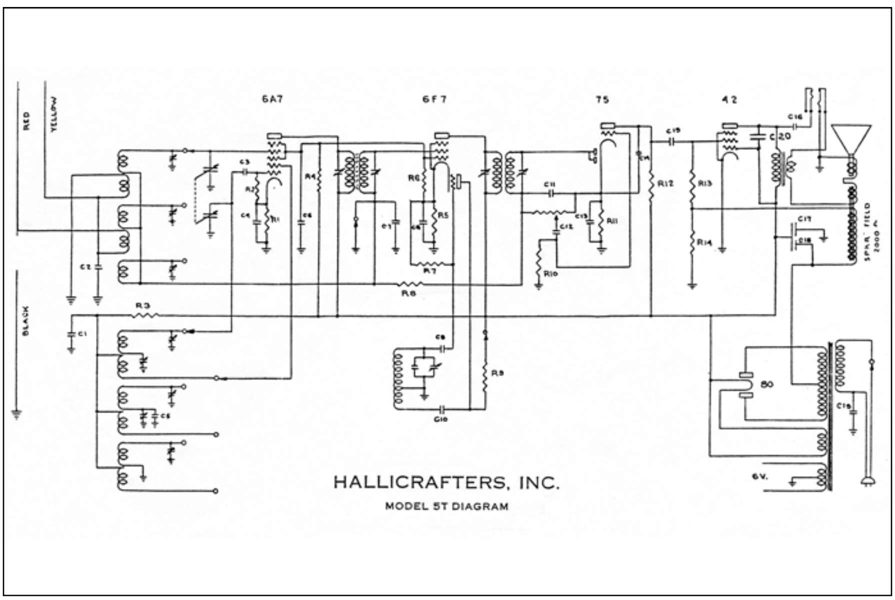


Fig. 3. Schematic of 5-T (see Ref. 7).

Restoration of the Hallicrafters 5-T Sky Buddy Models

At first glance, the two versions of the 5-T may look the same except for the celluloid dial, one with a boy and one without (Fig. 4). However, as will be explained later, the tuning changes go beyond a simple replacement of one dial for another.

When I saw my first 5-T With Boy I was intrigued by its appearance. I missed out on one at an AWA Conference auction and later I saw one exhibited by my friend William Ross at a Radiofest Conference in Illinois. I searched eBay to no avail, so I advertised in the Antique Radio Classifieds for six months without success. Then one came up on eBay and I bought it even though its panel was defaced and it was expensive. In order to get enough 5-T's to restore a 5-T With Boy and a 5-T Without Boy I ended up buying six 5-T's. Most were defaced or incomplete in one way or another. When a rare item does well on eBay, in my experience, others soon follow, at least for a while. It seemed I bought every one and then the supply dried up. As previously mentioned, Chuck Dachis, in his excellent book on Hallicrafters, states "Although somewhat costly, I will sometimes purchase as many as five radios of the same or similar model to get enough parts to restore one" (Ref. 1, p. 19). I have certainly found that to be true for the 5-T, especially since the models with and without the boy are different in a number of respects. The major problems I have encountered are defacing of the front panel, broken or missing dial belts, and, in 5-T's With Boy, missing belt tension idlers. When I find one with a near-perfect panel, then I do the restoration. The other sets provide missing or replacement parts.

The most common problem was an added send/receive switch installed on the front panel since the 5-T never had such a switch, an added pilot light, an

Fig. 4. Comparison of the 5-T Celluloid Dial With Boy and the one Without Boy showing on the dial. "SKY-BUDDY by The Hallicrafters". See back cover for color. The small red pointer is the 36 to 1 bandspread dial for the 0-100 outer ring of the dial. The longer beige colored pointer is to show frequency, the upper pointer for Band 1 and 3, the lower portion for Band 2.

added tuning eye, open or filled holes on the panel, and a "Boy" dial on a "Non-Boy" 5-T. Of course, several had a missing dial belt replaced by dial string in an attempt to replace one that had broken or worn out over time (Fig. 5). I am still able to pick up the proper dial belt (Fig. 6), the General Radio #116, on eBay or at radio flea markets.

Once you recognize that you cannot use parts from a 5-T celluloid dial Without Boy to repair a 5-T With Boy with damaged or missing parts, the major problem is replacement of the dial belt in the 5-T With Boy, which is usually broken or gone. It is a daunting task if you want to do it right since it requires disassembly of the dial assembly, including the dial glass, pointers, celluloid dial, and various other parts to reach the belt and replace it. For the 5-T With Boy, if the tension idler is missing you must first search for a replacement. Replacement of the dial belt is a laborious but satisfying process as outlined in Table I. For those who want to know more about replacing dial belts and making your own, there have been a number of papers in *Radio Age* over the years which may preclude the necessity to disassemble the tuner dial assembly if the proper dial belt cannot be found (see Ref. 3, 4 and 5).

The tubes (same in both versions) used in the 5-T Sky Buddy, from the Manual (Ref. 3) are as follows:

1st Detector-Mixer: 6A7
Beat Oscillator - IF Amplifier: 6F7
Diode Detector - AVC - Audio
  Amplifier: 75
Audio Power Output Stage: 42
Rectifier: 80.

The earliest 5-T With Boy has tabs incorporated on the metal ring holding the celluloid dial. They are frequently replaced with soldered metal tags since they break easily (Fig. 6). The beige colored pointer is held on

Fig. 5. Close up of the 5-T With Boy Sky Buddy tuning mechanism showing handmade string belt to replace the original belt. Also shown is the idler/tensioner under the string belt. Such string belts were used mainly to avoid the complex disassembly needed to replace the proper belt. Also shown is a soldered-on tab to replace one damaged in the past.

Fig. 6. Properly installed General Cement No. 116 Belt in a 5-T With Boy Chassis. Note glass, dial and hands have been removed and the soldered tabs bent out to facilitate removal of these parts. One of the tabs had broken in the past and was replaced.

TABLE I
Replacement of Dial Belt in a 5-T Hallicrafters Sky Buddy

(Based on experience of the author)

1. Remove 11 screws holding case to 5-T.
2. Remove nut holding the AVC switch.
3. Remove the following knobs: main tuning, band switch and volume control.
4. Remove four screws in bottom of 5-T holding chassis in place
5. Remove screw holding the two shielded wires going to BFO pitch control unit.
6. Rotate chassis carefully away from front panel to give access to belt.
7. Be sure you have a General Cement #116 Belt in hand or equivalent.
8. Bend small tabs away holding the convex dial glass. If you break a tab you can solder a replacement at the edge to hold the glass.
9. Remove the dial glass trying not to damage the dial seal on the edge. You will need it later to hold the celluloid dial in place.
10. Remove the main tuning indicator. In the 5-T With Boy it is held with a compression fit. In later versions (without a boy) it is held with a small screw.
11. Remove the red pointer being careful not to distort its fitting.
12. Under the red pointer is a washer which holds the pointer away from the celluloid dial. Retain this washer.
13. Gently remove the celluloid dial and set it aside.
14. Blow out or vacuum any dust or debris in the gears.
15. Now is a good time to check the dial bulbs to be sure they are good.
16. Remove the dial assembly by removing four screws on the right side and two on the left side for the 5-T With Boy.
17. Remove the one screw holding the main tuning stem bracket.
18. The belt can now be installed. 5-T's With Boy have an idler held in place by the belt. If this is missing, the belt may slip. The later 5-T Without Boy has a captive idler and a different gear arrangement.
19. Reassemble by doing the reverse of the above. Be sure the celluloid dial is properly oriented. Be sure the mechanism works smoothly.
20. Clean the dial glass and install by bending the clips at the edges.
21. Test the radio before reinstalling on chassis. Now is the time to check components, lubricate band switch, and check alignment.

with a push-on compression of a small diameter element from the condenser tuning mechanism (Fig. 7). The belt is held in tension by an idler on a flat tension spring arrangement. When the belt breaks after a time, the idler becomes loose and is frequently lost.

The later 5-T Without Boy also has tabs integrated into the metal ring holding the dial. The beige colored pointer is held in place with a small flat-headed screw while in the 5-T With Boy it is a pressed-on fit. The earlier celluloid dial with boy will fit in this later housing but would then not be original. The belt is the same as in the earlier 5-T, i.e. a General Cement #116 or a #119. The tension idler in the 5-T Without Boy is on a wire arm as part of a special tension spring (Fig. 8). If the belt breaks, the idler is still captured. The 5-T has a 36-1 gear ratio (Ref. 2).

The gear mechanisms looks the same but are different. The gears on the later version, without the boy, are held in place differently. Also, close inspection of the celluloid dials will reveal differences in the dial calibration for the three bands. Therefore, if one has a good celluloid dial with a boy in a defaced panel, it cannot simply be placed in the chassis of a later version with a good panel since the calibration will be off. I do not believe it would be possible to change the entire condenser and dial unit since the mounting holes are different even though the panel, case and many other circuit elements are similar.

Fig. 7. Parts of the 5-T With Boy: dial, dial glass, seal, celluloid dial, red pointer, washer and beige press-on pointer. The 5-T Without Boy has a similar dial with slightly different calibration, a larger hole in the red pointer and a beige pointer held in place with a screw.

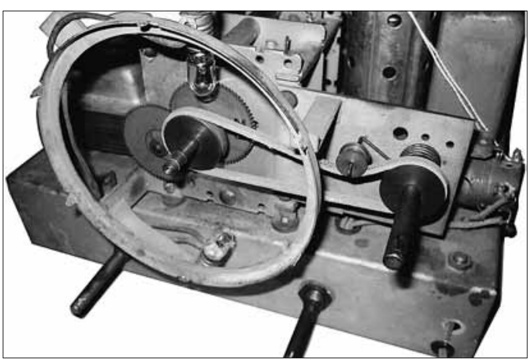


Fig. 8. 5-T Without Boy Chassis showing the captive idler/tensioner. The dial hands have been removed as have the mechanism covers.

Hallicrafters S-19 AND S-19R Sky Buddy Receivers

The S-19 (1938) and the S-19R Sky Buddy (1939) receivers (Fig. 9, 10 and 11) in most ways are two completely different receivers. They both look the same with black crinkle finish, the same size (17½" wide, 8¾" deep and 8⅝" high), and a speaker grill on the right side of the panel with a lower case "h" on the grill. Most other characteristics are different, as shown in Table II. Marc Ellis has described the Sky Buddy early series and restoration of an S-19R (Ref. 6).

Some of the tubes are the same and some are not (see Table III). The S-19 Sky Buddy had a frequency range of broadcast band to 18.5 MHz in three bands which did not include the popular 10-meter band. The S-19R Sky Buddy had a fourth band with a tuning range of 16 to 44 MHz well beyond that needed for ten-meters.

Marc Ellis has combined several articles in his *Popular Electronics* "Antique Radio" column into a single 28 page pamphlet "The Sky Buddy Saga" which discussed the 5-T (Ref. 6, p. 4), the S-19 and the S-19R (Ref. 6, p. 5). In his pamphlet Marc describes in detail restoration of an S-19R Sky Buddy (Ref. 6, p. 6–22). Marc found that it was necessary to remove the main tuning bandspread subchassis (an arduous task to remove and replace) (Ref. 6, p. 16) to gain access to the dial

TABLE II
Comparisons of the Sky Buddy S-19 and S-19R

S-19	360° Silver dial with engraved lettering One main tuning knob, 2nd dial is a logging scale. Phone jack on left. 3 bands. Broadcast band to 18.5 MHz. 5 tubes. 465 KHz IF. Send/Receive switch on right side of panel
S-19R	Major changes in dial: Somewhat over 180°, silkscreened lettering. Main tuning knob and a second bandspread tuning knob. Phone jack on right. 4 bands. Broadcast band to 44 MHz (includes 10 meter band). 6 tubes. 455 KHz IF (made standard by industry). Send/Receive switch on the left side of panel. Early version: Three slide switches on panel. Used 6Q7 and 6K7 tubes. Late version: Two slide switches and one toggle switch (the Send/Receive). 6SK7 tube used in place of the 6K7, and a 6SQ7 used in place of the 6Q7.

Fig. 9. Hallicrafters S-19 Sky Buddy.

Fig. 10. Early Version of Hallicrafters S-19R Sky Buddy. All switches are slide type.

Fig. 11. Later Version of Hallicrafters S-19R Sky Buddy with send/receive toggle switch.

TABLE III
Tubes Used in the Sky Buddy S-19 and S-19R

Function	S-19[1]	S-19R[1]
1st Detector-Mixer	6K8	6K8
IF Amplifier	6P7 (late 6L7)	6KL (late 6SK7)
Diode Detector, AVC, Audio Amplifier	6Q7 or 6SQ7	6Q7 (late 6SQ7)
Audio Output Stage	6K5 or 6K6	41
Rectifier	80	80
Beat Frequency Oscillator (BFO)	---	76

(1) Source: Operating Instructions for Sky Buddy S-19 (Ref. 8) and S-19R (Ref. 9).

drive system and to replace the shock-absorbing grommets which had hardened with age (Ref. 6, p. 13).

The schematic for the S-19 is shown in Figure 13 and for the S-19R in Figures 14–16. The separate bandspread on the S-19R is somewhat unique in that a small condenser is electrically part of the main tuning condenser including the stator with a separate rotor section, much smaller than the main condenser but an integral part of it, driven by a gearless mechanism, a dial string, with an entirely separate bandspread tuning knob. Early (Fig. 10) and late (Fig. 11) versions of the S-19R were made. Figure 12 shows a comparison of the S-19 and S-19R dials. Table II compares the S-19 and S-19R early and late versions. Figure 13 shows a schematic of the S-19 without external battery connections (octal plug in rear panel) and the same for the S-19R is shown in Figure 14. Figure 15 shows the schematic of the S-19R with external battery provisions and Figure 16 shows the connections for the

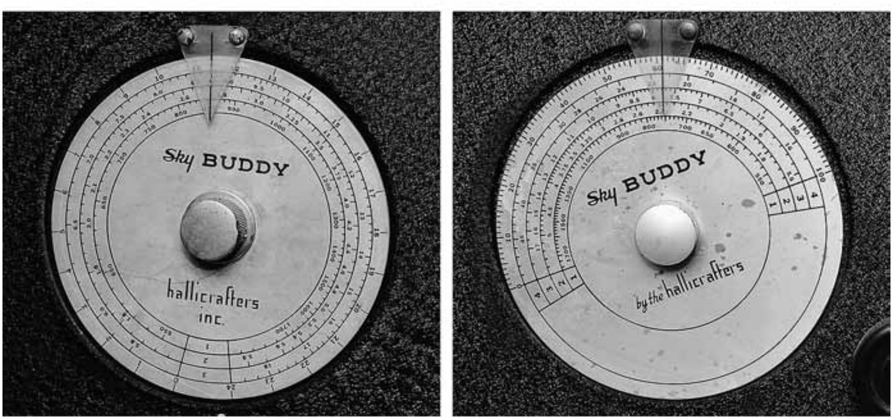


Fig. 12. Comparison of the S-19 and S-19R Dials.

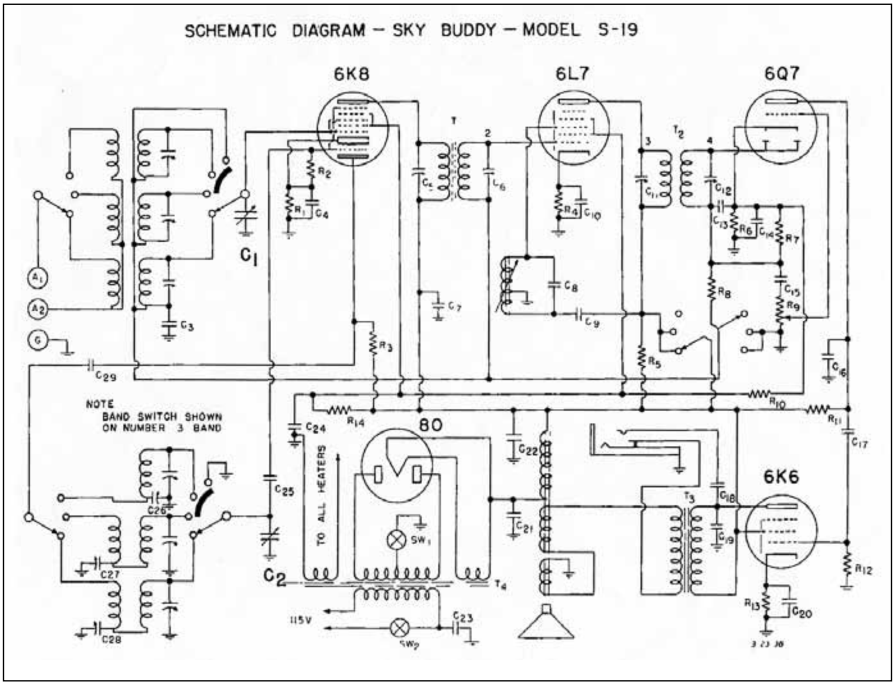


Fig. 13. Schematic of S-19. Battery connections not shown. (See Ref. 8).

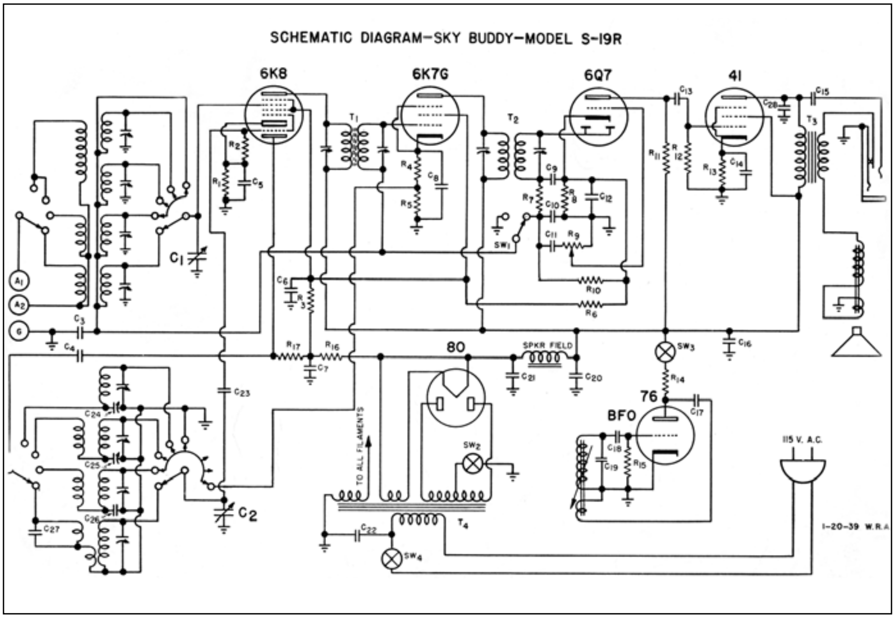


Fig. 14. Schematic of S-19R Battery connections not shown. (See Ref. 9).

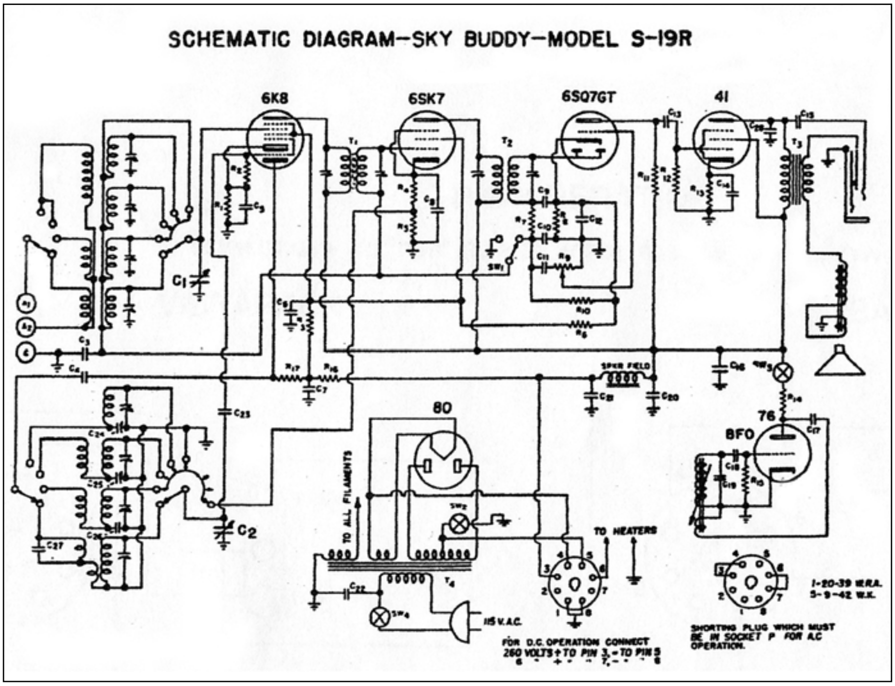


Fig. 15. Schematic for S-19R showing external battery connections.

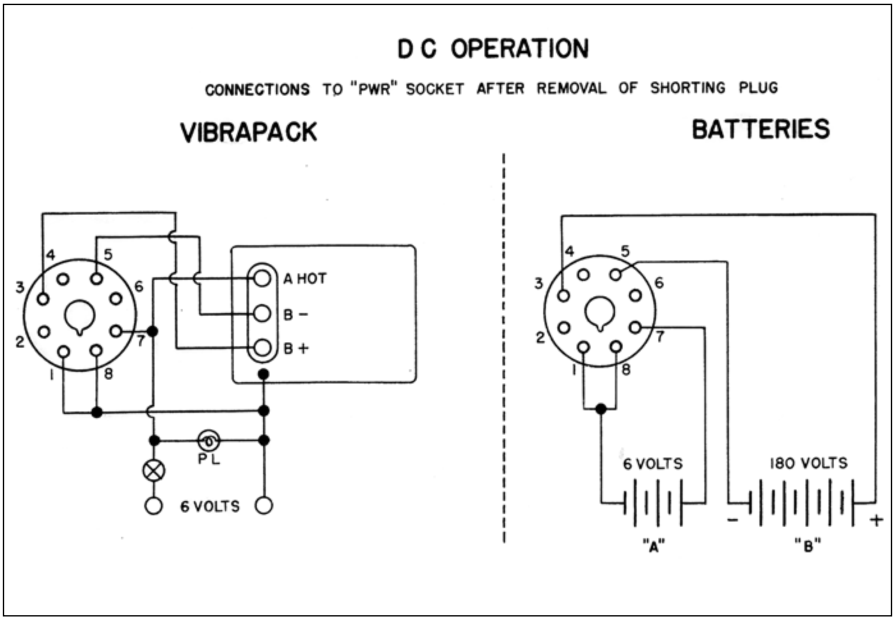


Fig. 16. Connections for Battery or Vibrapack Power Supply (see Ref. 9).

external battery and Vibrapack power supply. Both my S-19 and S-19R receivers had the actual female socket on the back chassis. Of the two, the S-19 is very rare and the S-19R less rare because many more were manufactured. Both were priced at $29.50 (Ref. 1, p. 36).

As shown in Table III, both the S-19 and the S-19R had some tubes which changed over time. The S-19 used a 6F7 (later a 6L7) as a dual function tube whereas the S-19R had a 6K7 (later a 6SK7) as an IF amplifier only. The S-19R used a separate tube for its BFO, a type 76.

Hallicrafters S-119 Sky Buddy II and Kit Form M S-119K

The S-119 Sky Buddy II was introduced in 1961 fully assembled and in kit form in the S-119K. It sold for $39.95 in kit form or for $49.95 fully assembled. The S-119 was the hundredth model since the S-19 Sky Buddy (Reference 1, page 21). The receiver (Figure 17) had three bands covering 535 KHz to 16.4 MHz and a 455 KHz IF. It had a ferrite rod antenna for the broadcast band. The dial is somewhat similar to that found in the S-19.

The S-119 is transformer operated and has a selenium rectifier. It used three tubes: 6BE6 Oscillator-Mixer, 6BA6 IF and BFO, and 6CM8 1st Audio and Audio Output. It used an IN295 Silicon Diode in the 2nd IF. See schematic (Fig. 18 and Ref. 10).

The S-119 was the only receiver since 1939 to use the name Sky Buddy (hence Sky Buddy II) and it was the last. It did not sell well and therefore is rare today, especially in good condition.

Fig. 17. Hallicrafters S-119 Sky Buddy II.

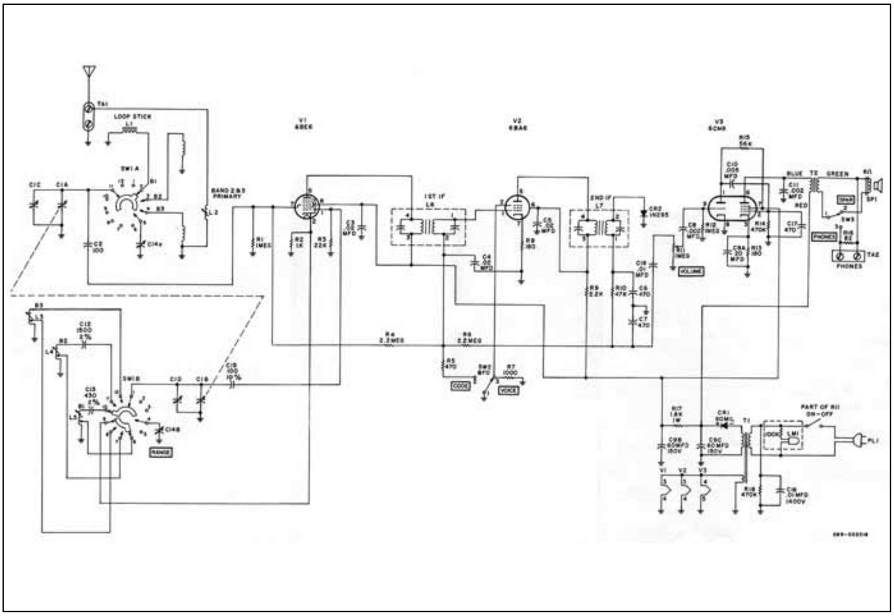


Fig. 18. Schematic of S-119 Sky Buddy II (see Ref. 10).

Conclusion

So ended the wonderful Sky Buddy receiver series which stands as one of the most attractive, well liked and very functional early Hallicrafters receivers.

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Photo Credits
All items shown in the Figures, including the rare 5-T With Boy, are in the collection of the author. All photos were done by Susan E. Golebiowski.

About the Author
Born on a ranch in South Dakota, U.S.A., without electricity except for batteries and no indoor facilities, radio was an important contact with the world for him. A current holder of the Extra Class amateur radio license, **Erich E. Brueschke**, BSEE, M.D., FAAFP, KC9ACE held the call WΦBPS in high school in 1948. After graduating from the South Dakota School of Mines and Technology with a B.S. in Electrical Engineering, he went on to work for the Hughes Research and Development Laboratories in Culver City, California, for five years. There he specialized in magnetics and the effects of high vacuum on components. His last work there focused on the Surveyor spacecraft in 1961–1962, which landed on the moon in 1966. He left Hughes to attend medical school at Temple University School of Medicine in Philadelphia, Pennsylvania. After completing his medical training, he became a Captain in the United States Air Force at the Aerospace Medical Research Laboratories at Wright-Patterson Air Force Base in Dayton, Ohio. Subsequently he practiced family medicine in California and then joined the Illinois Institute of Technology Research Institute in Chicago, Illinois, where, as Director of Medical Engineering Research, he worked on artificial internal organs, including powering the artificial heart, for seven years. He then joined Rush Medical College in Chicago, where he was Chairman of Family Medicine, and Professor of Physiology and Molecular Biophysics. He was also Program Director for the Rush-Christ Family Practice Residency Program for 17 years, which trained over 100 family physicians. He subsequently became Dean of Rush Medical College for six years. He retired as Dean in 2000. He is currently the Distinguished Professor of Medicine at Rush Medical College at Rush University in Chicago. He has two patents issued and has published numerous papers in engineering, medical and scientific literature, and is a member of a number of professional societies. He has previously published in the *AWA Review* in 2010, 2012, and 2013. His major collecting and restoration interests are early scientific educational apparatus, crystal sets, early battery radios, Heathkits, and

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