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EDITOR

Ludwell Sibley, KB2EVN
Flemington, NJ

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THE COVER

NBC remote truck in San Francisco, 1931. See John Schneider's article for more details.

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CONTENTS

FOREWORD

This issue of the AWA Review presents a variety of material of historical value.

To follow up on his narrative of tube development by the General Electric Company in Review Vol. 4, John Anderson presents a study of the radio development and production activities at GE. His time period is the years before RCA became a manufacturing operation, preceding the division of resources between RCA and GE's own operations.

Two papers deal with signals intelligence and countermeasures. Bart Lee narrates the WW I vintage stories of Charles Apgar uncovering WSL's disguised signals, and of American radio intelligence on the Mexican border. George Sterling, head of the FCC's Radio Intelligence Division during the years of WW II, details the effective actions of his group in locating illicit radio stations, both within and outside U. S. territory.

Two additional items address vacuum-tube matters. Thomas Briggs' exposition of the life of Robert von Lieben and his LRS Relay gives the history of an electronic amplifier patented well before the de Forest Audion. Attila Balaton explains a wide variety of construction details unique to Western Electric tubes. His coverage will be of ongoing use to tube collectors in judging the manufacturing dates and general history of these collectibles.

An interesting item of broadcasting history is included. John Schneider describes the brief history of San Francisco as a major originating point for network radio programming, based on extensive interviews with pioneer network employees.

Finally, a unique contribution appears: David Kraeuter's tabulation of the United States patents of ten major radio inventors. Expanding on an earlier publication of the Pittsburgh Antique Radio Society, he cites over a thousand patents from some prodigious inventors. Some of those patents were basic technology; most are long forgotten. The far-reaching creative powers of their holders are visible in both the patents' sheer numbers and their scope: many were in fields wholly unrelated to electronics. The listing of Major Armstrong's inventions is of particular interest in 1990, the centennial of his birth.

The Editor

SUPPLYING TUBES, SETS, AND PEOPLE TO RCA: THE GENERAL ELECTRIC CONNECTION

John M. Anderson
Scotia, New York

INTRODUCTION

The armistice which ended hostilities in World War I also brought a rapid end to Government contracts for the manufacture of radio vacuum tubes and military communication sets. The General Electric Company had figured heavily in the supply of this equipment. Vacuum tubes were made at its Edison Lamp Works in Harrison, NJ, and at the National Lamp Works (Nela Park) near Cleveland, OH. The Nela plant alone had shipped 179,315 tubes in the years 1917-18 [1]. Transmitters and receivers were made in Schenectady, NY and at the American Marconi plant at Roselle Park, NJ.

Without the strong military market, few outlets for sales remained. The war effort had trained many radio operators who would enter the ranks of radio amateurs in coming years, but their demand for tubes and equipment had yet to blossom.

Other than that, the fractionated patent situation prevented sales to the general public and to commercial markets. No one company possessed adequate coverage to build and sell state-of-the-art equipment, and litigation for patent infringement was commonplace.

Because of this and the threat that the Marconi Company would monopolize international communications by deployment of the Alexanderson alternator, the U. S. Navy encouraged General Electric to form an "American" wireless company. Thus was born the Radio Corporation (10/17/19), followed quickly (11/20/19) by an amalgamation with and dissolution of the American Marconi Company, the latter secured from "English" Marconi, its parent. Soon cross-licensing agreements were made with American Telephone and Telegraph and Western Electric (7/1/20), and with the United Fruit Co. and Wireless Specialty Apparatus Co. (3/7/21). Westinghouse at first decided to compete with RCA through its subsidiary, the International Radio and Telegraph Company, but soon saw the advantages of joining. It cross-licensed on June 30, 1921. These agreements neatly resolved the patent difficulties. The Radio Corporation (of America) was then poised to enter the radio field.

RCA's first president, Edward J. Nally, came from American Marconi, as well as Elmer E. Bucher (of WW I textbook fame) to become its Commercial Engineer in Charge of Sales, and also David Sarnoff to be Commercial Manager. Ernst F. W. Alexanderson split his time with GE to become RCA's Chief Engineer. Alfred N. Goldsmith left the City College of New York to become Director of the Research Department, and, in effect, replace Alexanderson as Chief

Radio Engineer when Alexanderson went back to GE in 1923. For interested readers, the exhaustive narrative by Archer of RCA's formation [2] is a good reference.

GENERAL ELECTRIC'S PARTICIPATION

If the General Electric Co. was to supply RCA with equipment and vacuum tubes, as was the contractual intent, it must set up an internal organization to design and manufacture equipment adequate for the job. Edward P. Edwards, long associated with GE's Lamp Department, was tapped (4/11/21) to become head of the newly reorganized Radio Department. His charter was spelled out, ". . . immediate supervision of our radio manufacturing, selling, and engineering: the execution of our contracts with Radio Corporation or other customers: and in general for so directing our efforts that we may realize a profit and render good and satisfactory service to our associates and customers in the field of radio communication" [3]. Edwards' job was administrative. Technical direction was provided by Adam Stein, an ex-Marconi employee who became Managing Engineer of the Department. He brought A. F. Van Dyck with him to be Designing Engineer for Receivers and named a GE engineer, Walter R. G. Baker, as Designing Engineer for Transmitters. (It is said that television station WRGB was later named for the latter.) Baker had joined GE's Standardizing Laboratory, forerunner of the General Engineering Laboratory, in 1917 and had built transmitters under war contracts. After KDKA's eye-opening success with public broadcasting, he pushed for and was instrumental in setting up GE's first station, WGY, which went on the air February 20, 1922.

It is fair to say that KDKA came as a shock to the engineers at GE. They certainly had the wherewithal to broadcast, but it had never occurred to them that the public would be interested [4]. General Electric management was unquestionably disinterested, so much that the first station had to be "sold" on the basis that it would provide interplant communications [5]. WGY soon outgrew these parochial ideas and became a pioneering broadcast station. It also served as a high-power testing facility to try out new power tubes and circuits, operating finally in 1932 at more than 200 kW under the experimental call W2XAG (with UV-862 tubes in the final amplifier). Experience gained here was helpful in designing and installing the 500-kW RF stage of WLW in 1934.

In 1922 the Radio Department moved into building 77 in the Schenectady Works. It was here and in nearby buildings that the great majority of Radiola receivers were made for RCA in the 1920s. This was not a small operation. By 1926, 300 women worked on the third floor of building 69 alone, assembling variable condensers and winding coils [6]. One hundred inspectors kept control of quality for the overall operation of the department.

Radio tubes were designed and prototyped by William C. White and his coworkers. He was a section head in the Research Laboratory. Transmitter tubes were manufactured mostly by R. C. Robinson's group, also a section of the Laboratory, located on the first three floors of building 37. Receiving tubes continued to be made at the National and Edison Works, but Robinson also made some short runs.

In 1927 Baker took over as head designing engineer for both receiving and transmitting sets, and in 1928, when Stein left, he became Managing Engineer of the Radio Department. Shortly thereafter (1930) he left to work at RCA in Camden, NJ as Vice President in charge of engineering, then of both engineering and manufacturing, and finally as VP and General Manager of RCA. In 1935 he returned to GE, eventually to head all of GE's re-emerging radio business. In 1930 White broke with the Research Laboratory to form the Vacuum Tube Engineering Department. He feared that the developing depression would impact the Laboratory, and separately he could better protect his people [7].

RECEIVING TUBES AND SETS

General Electric came out of WW I with what can safely be called a complete series (for the time) of radio tubes. From the low-power VT-13, or "G" tube, to the 250-watt "P" tube, there existed a line which needed only little alteration before marketing by RCA [4]. In early 1922 the Radio Corporation's first catalog [8] listed the UV-201, which had been the VT-13; the UV-202, from the VT-14; UV-203, from the VT-18; and the UV-204, which had been the VT-10; see Figure 1. To this list were quickly added the UV-200, a gas-filled tube for detection; and the UV-206, a one-kW transmitting tube. Radio receiving sets in this same catalog were the RA, DA, RC, and Aeriola Junior, all of them coming from Westinghouse. It took GE a while to get the factory lines moving, but by 1922 they were able to offer the AR-1300, AA-1400, and ER-753 (Radiola I), whose prototype is shown in Figure 2. The combination of the AR-1300 (regenerative tuner) and AA-1400 (detector and two-stage amplifier), both modified from military receivers, became the Radiola V. It was derisively called the "box cars" by the engineers [5]. The ER-753 was the first crystal set made by GE in any quantity. It was tuned by a copper sheet which passed over the coil, and even though the main effect was probably to alter the coil inductance, it was referred to by the designers as tuning by the "loss method" [5].

When RCA first offered tubes and sets to the public, it became clear that sales were more dependent upon the original manufacturer's name, i. e., GE or Westinghouse, than had been imagined. To correct this situation, RCA decided to force the companies to exchange specifications and make identical products under the RCA name. Only in this way could the agreed-upon split of dollar sales (60% GE and 40% Westinghouse) be maintained. There resulted a strong competition to get each company's designs accepted by RCA, and a "supreme court" became necessary. The end result was that Alfred Goldsmith passed upon the technical acceptability while Elmer Bucher decided what would finally be marketed [9]. Bucher also assigned tube-designation numbers. George H. Clark of RCA had established prefix letters, for example the UV-series ("unit vacuum tube") for tubes [10]. A formal organization, the Radiotron Standardization Committee, was set up (Feb. 1924) for coordination of tubes. It had representatives from the GE Research Laboratory, GE Vacuum Tube Division (centered at Nela), the Westinghouse Research Laboratory, and the Westinghouse Lamp Company [4].

The issue of what filament voltage should be used for vacuum tubes was raised early. GE emphasized storage-battery tubes (five to six volts) while Westinghouse was pushing for dry-cell tubes (1.1 volts). The design of receiving sets re-

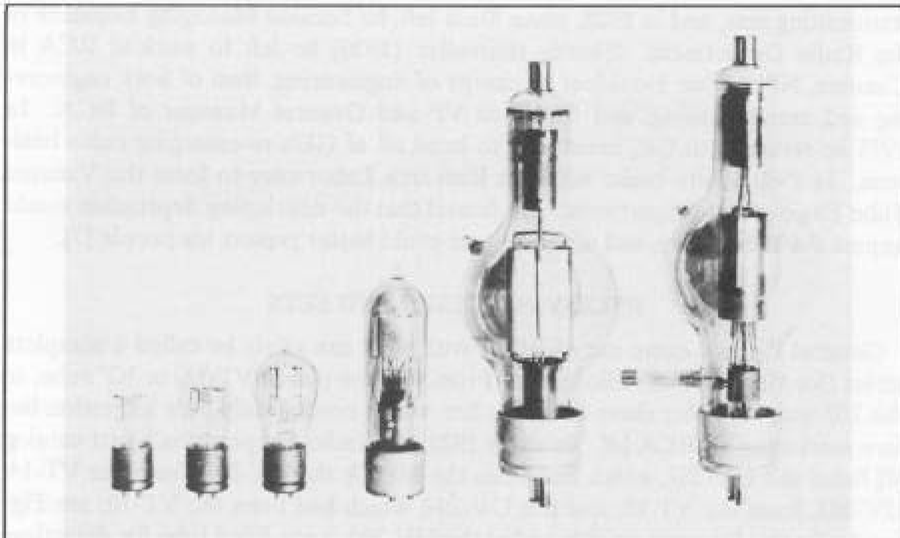


Fig. 1. The line of Radiotron tubes developed by General Electric as of November, 1921. From the left: UV-200, UV-201, UV-202, UV-203, UV-204, and UV-206. Photographed 11/3/21.

All photos: Hall of History Foundation, Schenectady, NY.

Fig. 2. A sample crystal receiver, Model 12-4A, which was a prototype of the model ER-753. Photographed November 30, 1921.

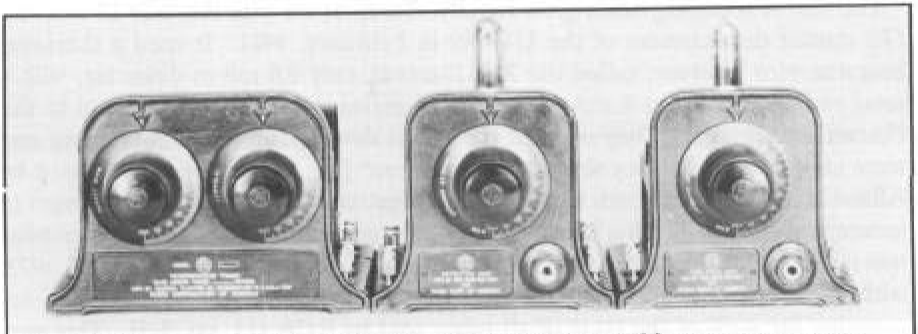


Fig. 3. The component approach to receiver design. This prototype, never produced, was photographed November 15, 1923.

volved in large measure on this choice, and both companies had much to gain or lose. Alfred Goldsmith was called upon to make a decision [9]. He concluded that, if the set used one or two tubes, those would be dry-cell tubes; if more than two tubes, storage-battery types. The competition in set design between manufacturers only intensified. White said in later years that he was convinced Westinghouse built their four-tube receiver (Radiola III and balanced amplifier) in two parts, each having two tubes, so that their tubes would gain acceptability [9]. It must be said that GE toyed with this approach themselves, probably to push their UV-199 dry-cell tube. Figure 3 shows a prototype set which was never produced. The influence of the Atwater Kent component approach is apparent. Always mindful of advertising importance, GE set up many photographs of human interest to accent their Radiolas; see Figure 4 as one example.

Fig. 4. This young lady, Barbara Wagoner, is engrossed in listening to a Radiola IV. Photograph taken during early 1923.

The line of receiving tubes grew rapidly. To compete with the WD-11 and -12, GE started development of the UV-199 in February, 1921. It used a thoriated tungsten wire filament, called the X-L filament, only 0.6 mil in diameter, with a total emission of about 8 mA. No great significance should be attached to the characters X and L. They masked the secret development of this filament and were chosen because they sounded "mysterious" [4]. Magnesium, developed by Albert Hull at the Research Laboratory as a getter of residual gases, was used to assure stability of the thorium emitting layer on the tungsten. Announcement was made by RCA in December, 1922, and it was offered for sale April 15, 1923, with sales that year of 450,000 units. In 1924 the sales were 1.8 million, accounting for 40% of the total of all tubes sold by RCA [11, pp. 5-9]. This percentage held during 1925 but by 1926 sales were down to 15%, only one-quarter of UV-201A sales. From there it was a rapid drop as interest in AC sets picked up. The UV-199 eclipsed the WD-11, and Westinghouse started making it in December, 1924. It was not manufactured without problems, however. On April 3, 1926 White recorded in his progress summary [11] "RCA preparing another complaint drive." A month later, on May 7th he wrote "RCA complaining loudly of poor quality."

Both Nela Park and Harrison Works benefitted from tube sales. In 1921 Nela shipped 58,960 tubes. In 1924 this was 3.2 million units to RCA and Cunningham [1]. We can gain some idea of the dollar amounts and importance to GE by comparing the tube sales with lamp sales. In 1925, U. S. sales of large incandescent lamps (40-watt and greater) amounted to 279 million units. In that year GE had about 60% of the domestic market, or 167 million units [12]. Taking the popular 60-watt size as a mean, the selling price of $0.32 (list) meant about $0.125 profit per lamp. Profit thus totaled $13,360,000. We are using here the following breakdown: 25% of list for production cost, 25% profit, and 50% of list to allow for distribution and discounts [12]. If Nela (National Works) and Harrison shared this equally, Nela's half was $6,680,000.

Now at this same time, 1925, Nela was making tubes at an annual rate of approximately 5 million, listing initially at about $6 each. Taking the above 25% profit, this implied that profit on each tube was $1.50 and the total profit $7.5 million. If these dollar amounts were correct, the profit from tubes rivaled or surpassed that from large lamps. However, this is not the whole story. In the first place, RCA tubes were selling on Cortland Street in New York City at less than $3 by 1925 [11]. Cost to dealer was probably below this, but not by much if the tubes were used as loss leaders. The effect of price collapse was obviously to reduce profits. Secondly, it seems unlikely that the cost of manufacture remained at $1.50, especially as manufacturing techniques improved. If the 60-watt lamp cost $0.125 to manufacture, it is more likely that the unit tube manufacturing cost was no more than $0.50, even with the additional hand work, allowing profit to be substantially maintained. The above is no more than an approximate calculation, because exact numbers cannot be found, if indeed they still exist, but it does indicate the growing monetary return from the radio craze.

Another winner, along with the UV-199, was the UV-201A. This thoriated-tungsten version of the UV-201 was also announced by RCA at the New York Radio Show in December, 1922. By 1924 it made up 53% of RCA's unit tube sales [11, pp. 17-20]. This percentage held until about 1927 when AC-powered sets took over. At first the price to consumer of the UV-201A was in the $6-8 range, but quickly dropped after other manufacturers got into the act and stole business from RCA. By November of 1927 the 201A was selling in NYC for as low as $0.75 [11]. However, the total unit sales of this tube type (all manufacturers) held at 50% of all tubes sold in 1927, and it was still 10.6% of RCA sales in 1928.

In the years 1923-24, E. W. Kellogg and Chester W. Rice in the Research Laboratory were working to improve loudspeakers [4]. The result was the electrodynamic speaker, which gave both louder sound and better frequency response. It was marketed in 1925 as the type 104 ($245). The improvements over horn-type speakers were reduced distortion and more bass response. It remained until after WW II to widen further the high-frequency response in affordable radios, adding the "lisp." But in mid-1924 the type 104 was a remarkable development. Electrodynamic speakers were well entrenched by the early Thirties. The author remembers, when servicing a Majestic model 90 in the late Thirties, the owner telling him that she liked the tone and he "better not do anything to change it."

In 1923, Edwin Armstrong, who in those earlier years was still a good friend of David Sarnoff, was working on a superheterodyne using a combination of his ideas and those of Harry Houck [2]. Armstrong was able to convince Sarnoff and the RCA board of directors that this "astounding achievement" should be marketed. GE and Westinghouse had their own ideas about set design, but nevertheless had the superhet shoved down their throats. Thus was born the Radiola Superheterodyne (portable), see Figure 5, and the Radiola Super-VIII (console). The receiver sold well at first and GE celebrated the 100,000th set off the line in December of 1924. A setup for testing tuning panels is shown in Figure 6.

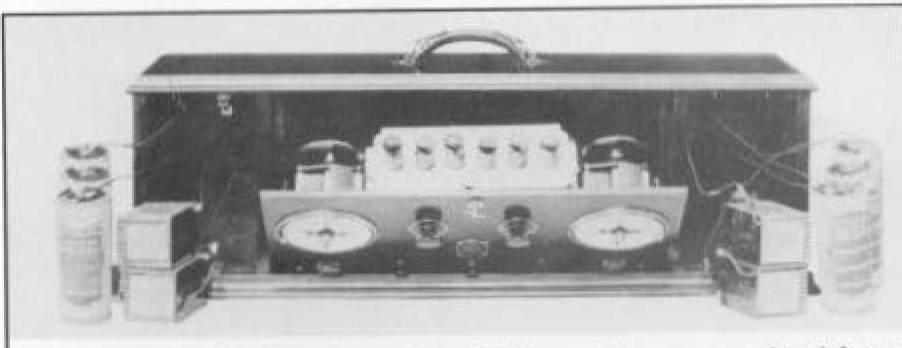


Fig. 5. The Radiola Superheterodyne with battery doors removed and front panel tilted down. Photographed December 24, 1923.

By this time, the middle Twenties, radio manufacturing at Schenectady was in full swing. Sets were assembled by women, as said earlier, and a huge "family" developed. They called themselves the "Radio Girls" and noontime parties were commonplace [6]. Male quartets, orchestras, and vaudeville shows entertained them, and were also broadcast over WGY. This all ended rather abruptly in 1929-30 when RCA took over manufacturing in Camden, NJ.

Fig. 6. A panel testing setup for the Radiola Superheterodyne. Photographed July 1, 1924.

Excess noise in the superheterodyne was traced by Albert Hull and Irving Langmuir of the Research Laboratory to "shot" noise in the mixer [4]. Hull, in the process of measuring this noise, constructed a high-gain amplifier using tubes with screens between plate and grid to minimize feedback. Connecting the screen to the positive power supply overcame the problem of high internal impedance in existing internally-screened tubes. The marketable results were the filament-type UX-222 (announced in November, 1927), and the UX-224 (4/30/29). The latter had an indirectly heated cathode for AC operation, complementing such other 2.5-V tubes as the 227.

Loudspeakers needed higher power-handling capacity and the UX-112, -120, -171, -210, and -245 followed. A list of tubes developed by RCA (GE and Westinghouse) during the Twenties is given in Table I.

TABLE I

TYPES OF RADIOTRON RECEIVING TUBES FOR RADIO BROADCASTING INTRODUCED BY THE R. C. A. UP TO THE YEAR 1930*

Year	No. of Types	Types
1920	2	UV-200, UV-201
1921	3	WD-11, WD-12, WR-21
1922	2	UV-199, UV-210A
1923	0	WD-12 (see note)
1924	0	
1925	7	UX-213, UX-120, UX-112, UX-210, UX-216B, UX-874, UX-876
1926	2	UX-171, UX-200A
1927	3	UX-280, UX-226, UX-227, UX-240, UX-222, UX-281, UX-171A, UX-112A
1928	1	UX-250
1929	3	UX-245, UY-224, RCA-221
1930	3	230, 231,232

* This table, assembled by W. C. White, is reproduced from Reference 4. Note that White lists the WD-12 under 1921. However, Tyne, in his Saga of the Vacuum Tube, states that the WD-12 was introduced by RCA in 1923 and was replaced by the WX-12 in 1925.

A partial list of RCA unit tube sales in percentage of total RCA tube sales can be assembled from White's progress books for the year 1929 [11]:

UY-227	17.73%	UX-120	0.42%
UX-245	10.73	UX-210	0.39
UX-201A	10.08	UX-200A	0.33
UY-224	9.80	UX-200	0.30
UX-171	7.79	UX-240	0.10
UX-199	4.37		
		TOTAL	62.04%

RCA was selling many other types; gas tubes, regulators, phototubes, transmitting tubes, etc.; to make up the residual 40%. For example, the 280, a huge success, had been announced only in 1927, and is not included in the above.

TRANSMITTING TUBES AND SETS

WW I was a proving ground for radiophone transmission, which clearly came out to be preferred over radio telegraphy [4]. After the war the Navy asked to upgrade their shipboard stations to 250-W and one-kW phone transmitters, providing the first real spurt of business for the new Radio Department. W. R. G. Baker was active in much of this work, giving him an edge when a manager for the transmitter part of the Department was established. The final-stage tube used for most of this work was the UV-204. A typical set is shown in Figure 7. About 1920, the United Fruit Company wanted to replace its spark transmitters in the Caribbean area [4]. It had a very progressive view of radio, due in large part to the competence of the engineers in its subsidiary, the Tropical Radio Company. GE benefitted greatly from this business, but more on this later.

First and foremost, RCA at its inception was intended as a communications company. Its task was to set up a network to handle traffic. Alternators were made in Schenectady and installed under RCA auspices at points in the U. S. and abroad. By April, 1922 GE had manufactured 17 large alternators, and an installation in Poland was planned. Early that year seven such stations were operating [13]:

Station	Wavelength	Frequency	Call
New Brunswick, NJ	13,600 m	22.06 kHz	WII
Marion, MA	11,500	26.09	WSO
Tuckerton, NJ	16,000	18.75	WGG
Kahuku, Hawaii	16,400	18.29	KIE
Bolinas, CA	13,300	22.56	KET
Caernarvon, Wales	14,200	21.13	MUU
Radio Central, LI	16,500	18.18	WQK

The stations in Hawaii and California handled the Pacific traffic, and others concentrated on Europe. Most messages were sent at 50 to 100 words per minute and received by tape with a tape readout machine designed by Alfred Goldsmith, shown in Figure 8. These were not small stations, either in cost (about $2 million) or size, see Figure 9. Each station had two 200-kW alternators; each alternator with its associated equipment required eight railroad cars for transport. Radio Central was the flagship station and showpiece. Along with New Brunswick, Tuckerton, and Marion, it had land lines directly to NYC. Rates for messages were considerably below those of the transatlantic cables. For example, to Great Britain (Caernarvon) the charge per word was $0.18 compared to $0.25 for cable [13]. To Japan it was $0.72, for a saving of $0.24. These stations with Alexanderson alternators, multiple-tuned antennas, and directional "barrage" receivers were state-of-the-art.

Further stations were sold, for example to Sweden in late 1924, but this happy state of affairs did not last. The Vacuum Tube Section under White was developing higher- and higher-power transmitting tubes. By 1921 the UV-206 at one

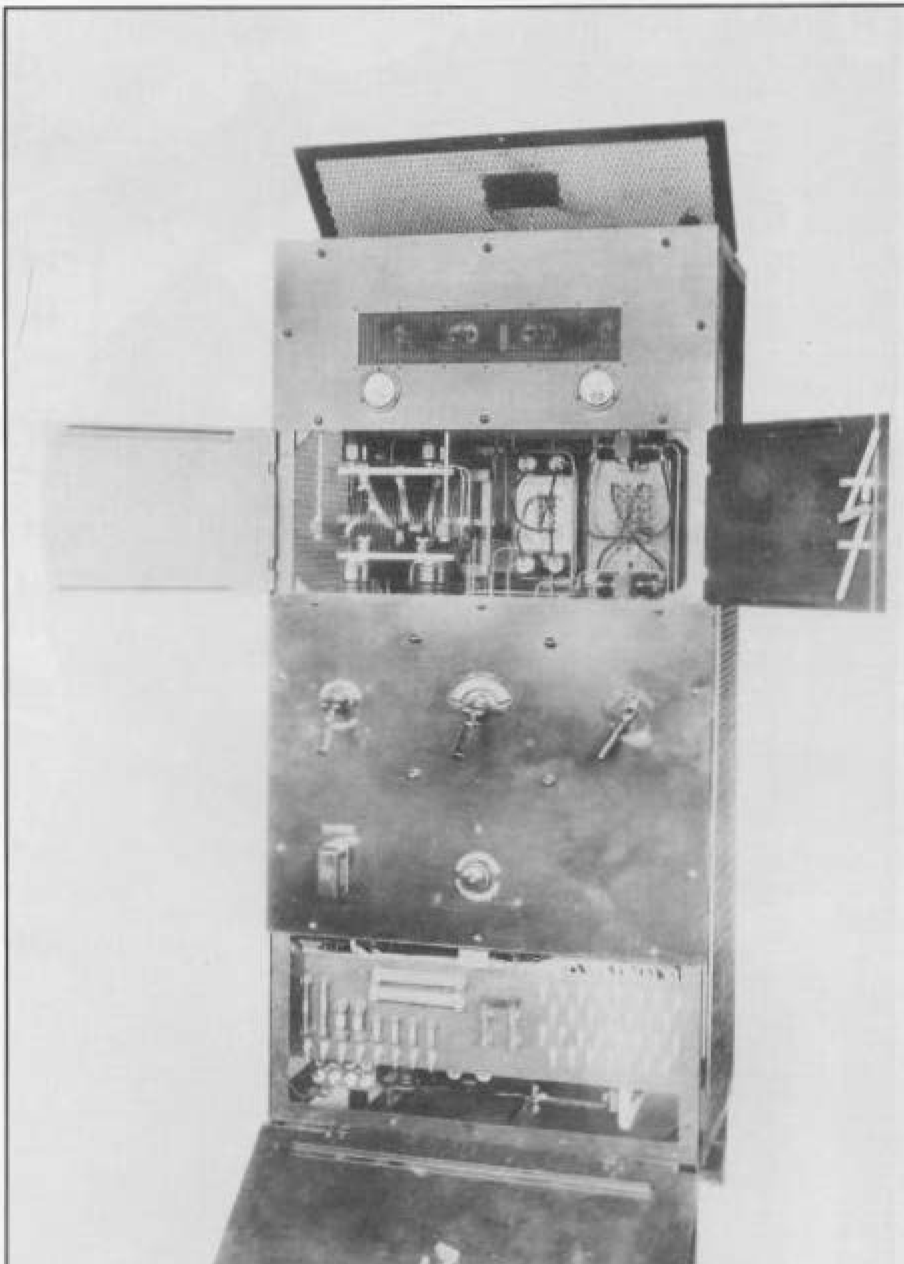


Fig. 7. The one-kW radio transmitter Model AT-702, typical of transmitters in the post-WW I period, using UV-204 or UV-206 output tubes. Photographed October 22, 1921.

Fig. 8. Ernst F. W. Alexanderson examining a tape from Alfred Goldsmith's high-speed ink recorder at the Riverhead station of RCA. Photographed May 26, 1922.

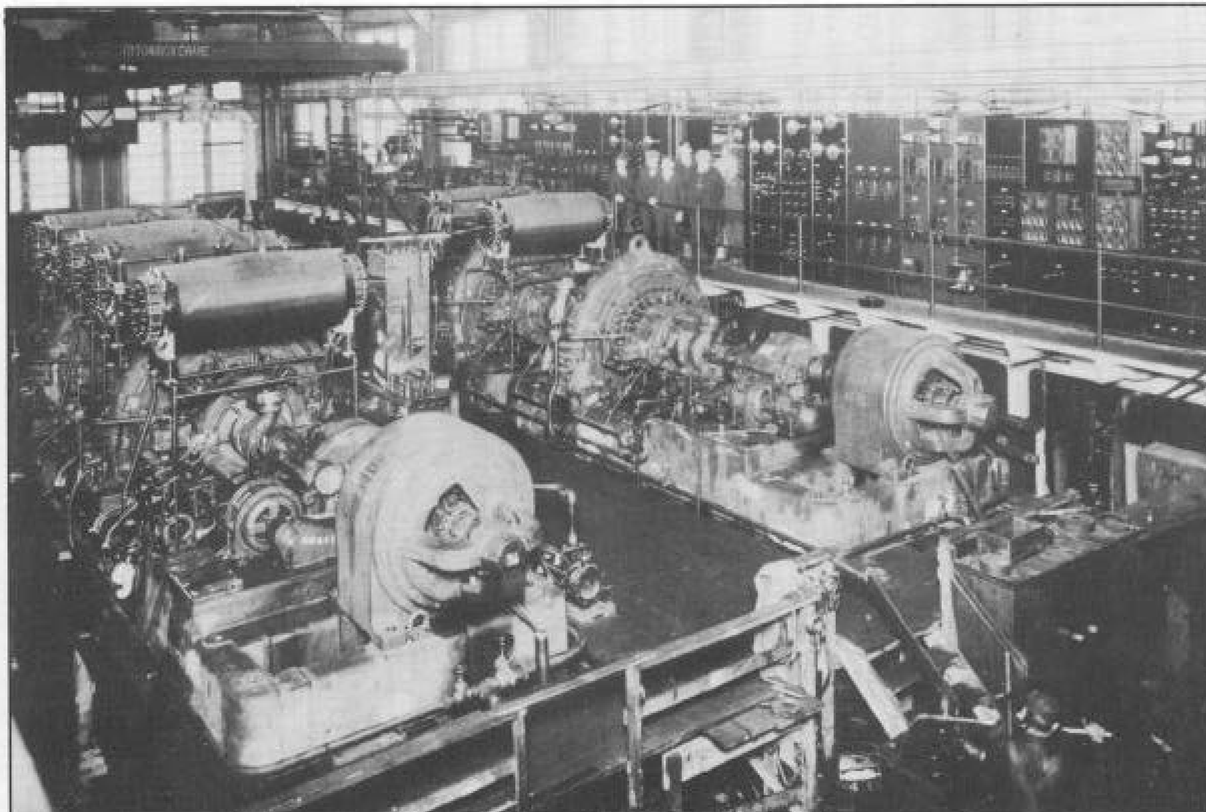


Fig. 9. Alternators being assembled and tested in Building 49 of the Schenectady GE Works. These particular machines, numbers 19 and 20, were shipped to Poland. Photographed January 31, 1922.

kW, and by 1922 the UV-208 at five kW, were ready for sale [4]. But even as they were in development, it became obvious that these tubes were pressing the then-reasonable limits of radiation-cooled anodes. Henry J. Nolte, in White's group, had started work in March, 1919 on a 20-kW water-cooled tube [11, pp. 11-49]. This tube, eventually to be the UV-207, shown in Figure 10, had a tortuous development. The anode was initially cut from a solid casting of copper. It consistently leaked air. There were seal problems, filament-to-grid shorts, secondary emission, etc. But eventually there emerged the first of a line of water-cooled tubes which played a major role in high-power broadcasting.

In the summer of 1922, installation of twelve 207s in parallel was begun at Rocky Point, LI, to see if they could replace the alternator. Baker, Irvin R. Weir, Nolte, H. D. Oakley and White, along with representatives from RCA, spent many hectic hours, night and day, until October, making the installation [4]. One of the major problems was parasitic oscillation. The difficulty of solution so impressed the engineers that for many years parasitics were called the "Rocky Point effect." The Telephone Company was likewise installing a phone set for transatlantic tests at 5000 meters. The two groups worked in friendly competition, but the Telephone installation was nearing completion first. GE had not finished the oscillator and driver. In desperation [14] GE engineers took an alternator to drive the grids of the 207s directly, and were able to carry traffic at 50 words per minute for 16 hours on October 14, 1922 [15].

Operators at Nauen, Germany were unable to tell any difference from the alternator, even though the greatest output was never much over 100 kW [14]. A schedule for 10 hours followed with Caernarvon on October 21. This success spelled the end of new installations of the expensive alternator. UV-207s were used to upgrade WGY and many other broadcast stations, until superseded by even higher-power tubes, such as the 100-kW type 862 shown in Figure 11. The 862 was the highest-power tube developed by GE. They decided that any reasonable demand for power could be met by paralleling 100-kW tubes.

The first extensive sale of higher-power transmitters using 207s was to the United Fruit Company during 1922-24 for their Caribbean operation. Locations were New Orleans, Miami, Guatemala, Honduras, Nicaragua, and Panama for a total of six sets [16]. The installation at Tegucigalpa, Honduras was in a remote area and was by far the most difficult, made more so because it was carried out in the midst of a revolution [14]. Irvin Weir, who was sent to do the final set up and tuning, had to be spirited through the battle lines to escape. Such a transmitter using a UV-207 is shown in Figure 12.

Along with the revolution in power triodes (and in Honduras), an equally important one was taking place in rectifiers. It was common practice in the early Twenties to omit the grids from triodes and make rectifiers (kenotrons) to provide a DC plate supply. The UV-202 without a grid became the UV-216, the UV-203 the UV-217, the UV-206 the UV-218, and the UV-208 the UV-219. The water-cooled tube, UV-207, became the UV-219. But high internal impedance gave an undesirable voltage drop and power loss. Also, the vacuum had to be very good to prevent filament damage by positive-ion bombardment. Albert Hull discovered that if the ion kinetic energy could be kept below about 40 eV, sputtering damage to the filament (even an oxide-coated one) did not occur, or at least was much reduced [17]. He introduced a droplet of mercury to

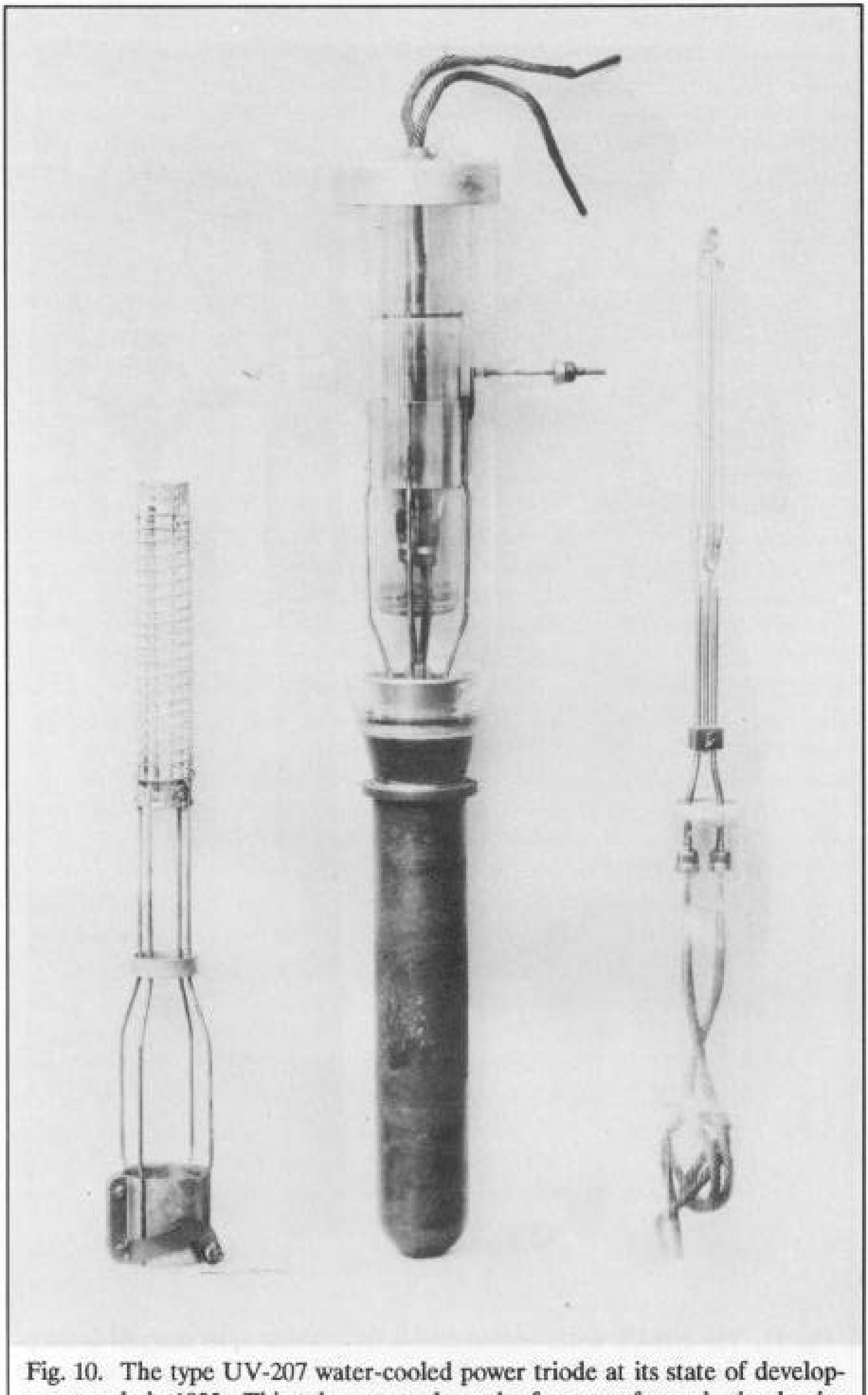


Fig. 10. The type UV-207 water-cooled power triode at its state of development early in 1923. This tube was perhaps the foremost factor in the demise of the alternator.

Fig. 11. The 100-kW water-cooled tube is the UV-862 at its stage of development in December, 1926. The rightmost appendage is a gas-gettering pump to maintain good vacuum in the earlier tubes. The small tube being held is the UV-207, the first of the water-cooled "metal" line.

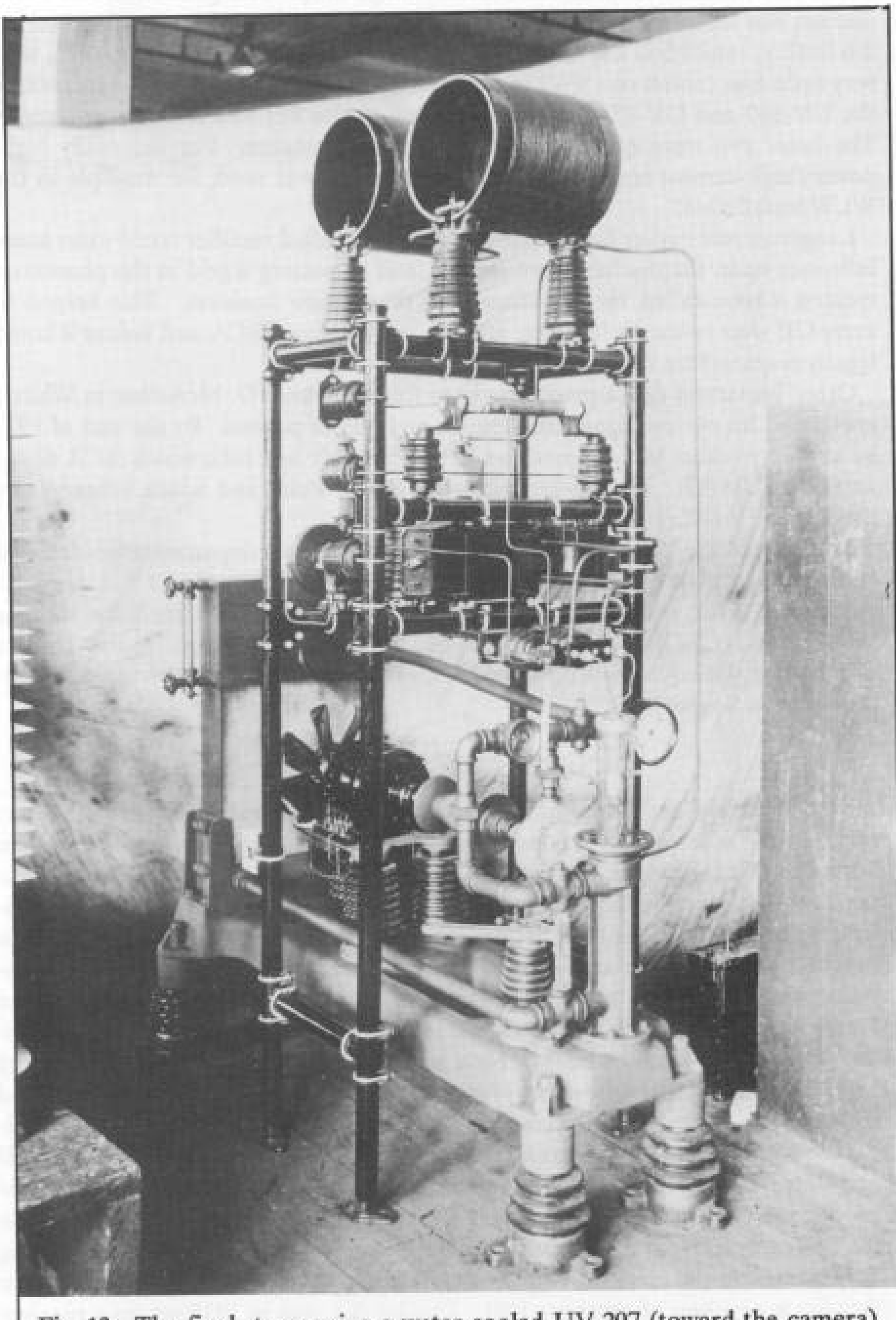


Fig. 12. The final stage, using a water-cooled UV-207 (toward the camera), of a 20-kW transmitter used in the United Fruit stations. It was driven by a UV-206. Photographed July 16, 1923.

the tube, and the resulting fully established mercury-vapor plasma between the anode and filament reduced the overall voltage drop. The phanotron was born. Success was immediate. South Schenectady, General Electric's experimental radio facility, tested 550 kW at 22.5 kV into a water load in November, 1926, with very little loss (about one kW) in the rectifiers [4]. For high-power applications the UV-869 and UV-857 were sold, as well as the 872 and 866 for low power. The latter two were quickly adopted by radio amateurs. For the really high-power/high-current end of the line, the RCA-870 was used, for example in the WLW installation.

Langmuir had earlier found that a grid in a gas-filled rectifier could exert some influence upon the discharge breakdown, and so putting a grid in the phanotron created a tube called the thyratron, and thus a new business. This helped to carry GE over in the early 1930s, after separation from RCA and before it could legally manufacture radio tubes and sets.

Other important developments were to follow. Elmer D. McArthur in White's group had his eye on higher frequencies and higher powers. By the end of 1927 he and co-workers had reached five kW at 50 MHz in a tube which RCA designated the UV-858. Testing grounds were Rocky Point and South Schenectady. Later the UV-846 (1931) gave 1.1 kW at 120 MHz.

Throughout the 1920s GE built many transmitters in a department headed first by Baker and then Conan A. Priest in buildings 77 and 89. Priest had designed the United Fruit transmitters. Broadcast transmitters were built for stations WWL, KGO, CKGW, WBT, WHAS, and KLS, to name a few. In the Thirties and Forties the equivalent department moved into FM and television transmitters, built in Schenectady.

CONCLUDING COMMENTS

The decade of the Twenties was turbulent, explosive, excessive, and about any other strong adjective one chooses to use. Radio was introduced to 7.5 million homes in this short span of time [18]. But the fabric of which RCA was made began to fall apart by the late Twenties. Because of perceived or real monopolistic practices, RCA-bashing became commonplace. By 1929 it was decided to forestall possible court action by moving all manufacturing to RCA in the recently acquired Victor plant in Camden, NJ (sets), and the Edison Works in Harrison (tubes). Many engineers and managers from GE also made the transfer. One by one the tube lines at Nela and Schenectady were transferred and by 1930-31 most popular types had been moved. Transmitting tubes were shifted more slowly, while RCA continued to buy from GE and Westinghouse. The final blow came in 1932, nevertheless, through a court action which prevented GE and Westinghouse from full re-entry to the market until May 21, 1935. Receiver production at GE stopped completely for all practical purposes. But, looking to the future, in 1933 Ira J. Kaar was transferred from the Transmitter Engineering Department to the General Engineering Laboratory with orders for his group to develop a new line of receivers [19]. This he did, and in 1935 set up a receiver manufacturing department at Bridgeport, CT in a plant purchased by GE after WW I from Remington Arms [4]. Another group headed by George F. Metcalf was set up under White to look into new vacuum tubes. White had the Vacuum

Tube Engineering Department (75 people), after spinning off from the Research Laboratory. Out of Metcalf's group came the completely new metal receiving-tube line, first manufactured as samples by Nela Park (1934), then by RCA beginning in 1935, and eventually by GE in Owensboro, KY at a plant purchased from Ken-Rad (1944). White remarked in later years, "Over the years, only one other tube producer, Ken-Rad, became a real competitor." [4].

The years of the Great Depression were slim for the VT Engineering Department, but it succeeded in the development and sale of new industrial tubes for spot welding, motor control, theater lighting, railway control, and the like. Non-radio tube sales for 1930 were $130,000. In 1937 they had grown to $400,000, right in the depths of the Depression.

The object of the breakup of the original RCA agreement was to allow RCA to be prominent in radio, and GE was to benefit by owning RCA stock. RCA paid GE $100,000 for the privilege of learning about the metal tube, and also continued to fund VT research at GE for a number of years [4]. But GE was motivated to get back into tubes and sets, and this they did as soon as the law allowed.

ACKNOWLEDGEMENTS

The author has benefitted considerably by conversations with William Teare and Rudolph Dehn, both of whom worked with W. C. White, and also Ray Williamson who joined the Transmitter Department about 1930. The Antique Wireless Association Museum graciously permitted study of the progress summary books kept by White in the years 1920-1950 and other material from the White file. William M. White, son of W. C. White, loaned the author some of White's personal papers and organization directories which were helpful to establish a time-and-people framework. Copies of interviews conducted with radio pioneers by the Oral History Project of Columbia University, New York City, were readily provided. These interviews are copyrighted by the Columbia University Board of Trustees; permission to reference them is gratefully acknowledged. The photographs are from the files of the Hall of History Foundation, Schenectady, NY 12345.

REFERENCES

1. J. W. Fellows, "Now That We All Have Radios," Light, Dec. 1924, p. 13. See also "The National in the World War," General Electric Co., June 1920.

2. G. L. Archer, Big Business and Radio (New York: The American Historical Company, Inc., 1939). See also History of Radio to 1926, by the same author (New York: The American Historical Society, Inc., 1938).

3. Organizational announcement issued by E. W. Rice, Jr., president of General Electric, Hammond File L-1145, Hall of History Foundation.

4. W. C. White, "Early History of Electronics in the General Electric Company," written 1953-55, File TK-7810, Hall of History Foundation.

5. Interview with W. R. G. Baker conducted by the Oral History Project of Columbia University; see acknowledgements.

6. Elizabeth D'Arcy, Radio Department "Women's Section," General Electric

Schenectady Works News, Feb. 19, 1926, p. 20. Copy at the Hall of History Foundation.

7. Conversation between the author and William M. White, son of W. C. White.

8. Catalog, "Radio Apparatus for Amateur and Experimental Use," Seventh Ed. (New York: Radio Corporation of America, Apr. 1, 1922).

9. Hammond File 54-9, Hall of History Foundation.

10. Henry Schroeder, "The Development by the General Electric Company of Radio Receiving Tubes," AWA Museum Library, Holcomb, NY 14469.

11. W. C. White Progress Summary Book #1, AWA Museum Library.

12. A. A. Bright, Jr., The Electric Lamp Industry (New York: The MacMillan Co., 1949).

13. As [6], April 7, 1922, p. 7.

14. Interview with Irvin R. Weir conducted by the Oral History Project of Columbia University.

15. As [6], Nov. 3, 1922, p. 24.

16. As [6], Oct. 5, 1923, p. 28.

17. Interview with Albert Hull conducted by the Oral History Project of Columbia University.

18. Alan Douglas, Radio Manufacturers of the 1920s, Vol. 1 (Vestal, New York: The Vestal Press, Ltd., 1988), p. xxi.

19. J. A. Miller, Workshop for Engineers (Schenectady, NY: The Maqua Press, 1953), p. 68.

John M. Anderson

John M. Anderson was born in Kansas City, Missouri and attended local schools until entering the U. S. Army in' 1943. During World War II he headed a radio-transmitter maintenance team attached to the Army Airways Communication System. After the war he attended the University of Illinois, receiving a PhD in electrical engineering in 1955. In addition to regular studies, he worked as a research associate in the field of electromagnetic-wave propagation in ionized gases. In 1955 he joined the Technical Staff of the GE Research Laboratory and investigated in the areas of gaseous electronics, power circuit breakers, and electric-discharge lamps. For the years 1964-70 he taught plasma measurements at the Rensselaer Polytechnic Institute as member of the adjunct staff. In 1966 he was Chairman of the Schenectady Section of the IEEE. John retired from GE in 1987 and is presently engaged in consulting and researching early radio history. He is a Fellow of the American Physical Society and the IEEE. He also serves as Trustee of the Hall of History Foundation in Schenectady.

AMERICA'S WIRELESS SPIES

Bart Lee
San Francisco, California

INTRODUCTION: WIRELESS IN THE SERVICE OF AMERICAN INTELLIGENCE AGENCIES

Since its earliest days, radio has had military and diplomatic significance, ranging from the tactical to the highest levels of national security. "Wireless," as it was called before broadcasting, was short for wireless telegraphy. Wireless messages were used for military as well as commercial purposes within a few years of the development of the art by Guglielmo Marconi and his 1901 transatlantic tests.

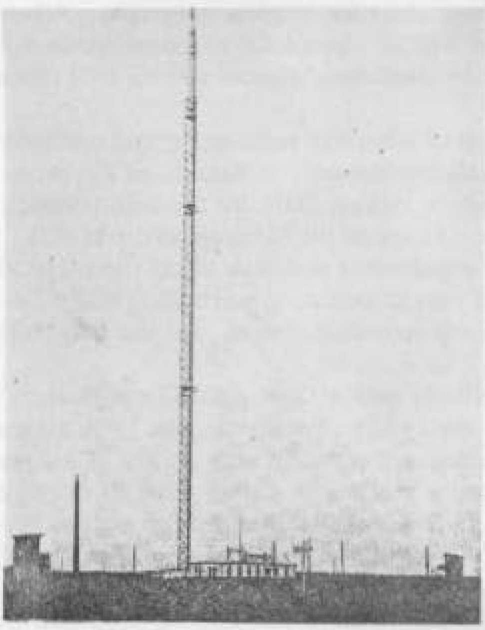
This article is about the beginnings of American radio spying and counterspying, the first U. S. SIGINT - signals intelligence. It focuses on the work of American radio amateur Charles Apgar, callsign 2MN, for the Secret Service in 1914-15 and on the U. S. Army Signal Corps on the Mexican border in 1916. Its purpose is to bring out previously unpublished materials about these episodes and to connect the technology of the time to its history, particularly Major Edwin Armstrong's regenerative circuit, early recording devices, and the first mobile wireless operations.

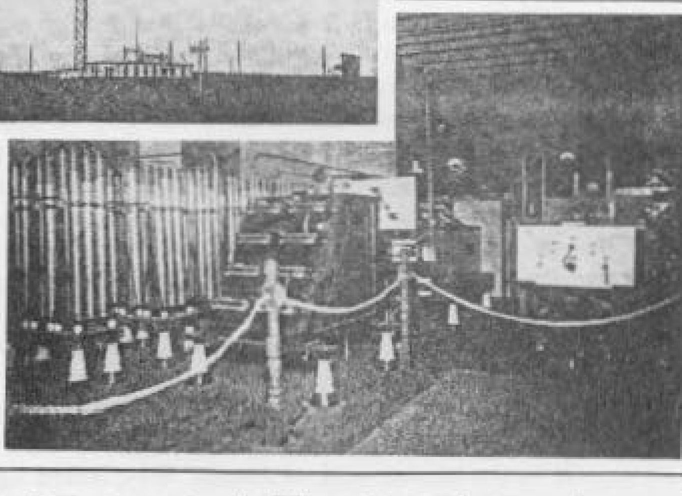
As soon as wireless carried traffic of military and political significance, its interception and decoding became worthwhile. To this day, the U. S. National Security Agency (NSA) and its companion Central Security Service (CSS) practice these black arts [1]. They have a continuous lineage back to the Signal Corps and the Secret Service of the U. S. Treasury Department as early as 1914.

Rexford M. Matlack, W3CFC, of AWA, published an article in 1976 [2] on the 1915 counterespionage adventures of Apgar, to whose success in recording spark signals much of this article is devoted. Matlack has given a slide and tape presentation to the AWA on Apgar's achievement. The latter died at his home in Westfield, NJ in 1950, at the age of 85. His obituary reports that he was an amateur astronomer [3]; Matlack has indicated that Apgar was a professional statistician. His amateur intelligence work started, however, in August 1914, on the eve of the Great War. In the several days just before the outbreak of hostilities, Apgar intercepted coded German wireless traffic of wartime significance from the Atlantic Communication Company (Telefunken) wireless station, WSL, at Sayville, Long Island, for the United States government.

Mr. Matlack's article reproduces a newspaper article datelined Westfield, August 1, 1934, indicating that Mr. Apgar had done wireless intercepts of German traffic from Sayville in the second week of August, 1914, before fighting commenced. Matlack says that a banker neighbor of Apgar's with military connections, one Colonel Parsons, put up half the money for two cylinder phonographs, to permit uninterrupted recordings off the air, and suggests that Col. Parsons may have played a role in acquainting Radio Inspector Lawrence J.

The Sayville Station





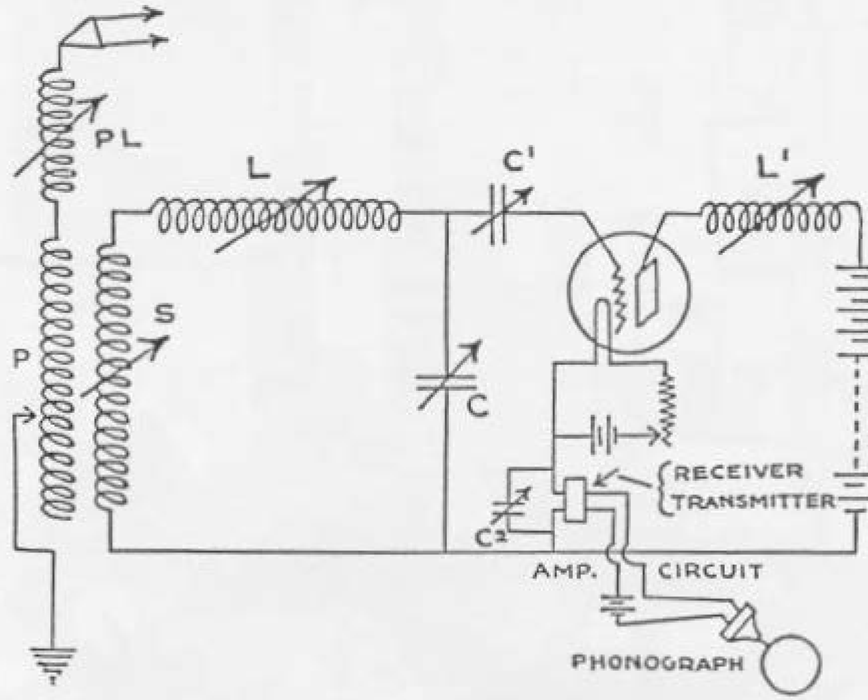
Top: operating room; center: building and tower; bottom: the transmitter.
Wireless Age, Sep. 1915

Charles Apgar at his receiver and recorder, after WW I.
Popular Radio, Nov. 1923

Krum with Apgar and thus instigating the 1915 recordings.

By 1915, both Apgar and WSL employed Armstrong's regenerative circuit with the still-new vacuum tubes in their receivers; indeed, WSL was one of the *first* commercial users. The virtues of this detector, patented October 6, 1914, led to celebrity: "overnight the feedback circuit became the sensation of the wireless world." [4]. According to Matlack, who had many discussions with Apgar's late son Lawrence, Edwin Armstrong and Charles Apgar may well have been acquainted inasmuch as active amateur radio operators of the day in the New York area tended to know one another, if only by spark QSOs.

At the start of the War, there was little precedent for the military use of wireless, or for its interception. In 1908 the Austrians monitored Italian military transmissions both on land and at sea with regard to a diplomatic crisis of the



Schematic of Apgar's Armstrong-circuit receiver and recorder.
Wireless Age, Sept. 1915, p. 879.

day, Austria's annexation of Bosnia [5, p. 1]. The U. S. Navy itself had done its first testing of wireless communication at sea as early as 1903; the Japanese and Russians had used wireless in their 1905 war, listening to each other [6]. In 1911 the Austrians again intercepted military communications of the Italians, and the Turks as well, regarding their brushfire war in Libya [5, p. 1]. The French and Austrians had SIGINT agencies operating before the War; the Germans did not [5, p. 3, 7].

The first military use of wireless was as early as the Boer war in 1899-1900, but it failed for want of good antennas [8, 9]. The British Navy inherited the equipment (British Marconi and captured German Siemens gear), and used it successfully in the coastal blockade of 1900, the first successful military use [8, p. 33]. Camel-borne wireless sets went on the British Somaliland expedition of 1903 [8]. Back in England in 1903, Lodge-Muirhead gear traveled on maneuvers with one army corps, while Marconi equipment went with another [10, p. 175 n. 98]. In America in 1911, a commercial interception of a wireless press-related message in California resulted in a much publicized criminal charge and dismissal [11], sensitizing the wireless community to the issue of interception.

With the interceptions of Charles Apgar and the monitoring on the Texas border by the Signal Corps, the U. S. government entered the age of SIGINT. In a recorded 1934 NBC radio interview, Apgar tells what he did, how he did it, and how his recordings led to the U. S. seizure of WSL in July of 1915.

Americans thus matched the prewar intelligence work of English Marconi

Company engineers. In the days before the August 1914 commencement of hostilities, the Marconi staff, like Apgar, were using the vacuum tube in a receiver. They intercepted German naval traffic and provided it to the British Admiralty. This was the beginning of British SIGINT activity [12]. British amateur and Post Office stations also intercepted German naval messages for the Admiralty after the war began [8, pp. 57-58].

The infamous Zimmermann telegram of 1917, deciphered by Admiralty codebreakers, precipitated America's entry into the war against the Central Powers. Arthur Zimmermann, the German Foreign Minister, offered Mexico a return of the American Southwest if she would join the Central Powers and declare war on the United States. American outrage led to our own declaration of war in April of 1917 [7, p. 620; 13]. The year before, the U. S. had sent a "Punitive Expedition" into Mexico, under the command of General John J. "Black Jack" Pershing, to deal with Francisco "Pancho" Villa and his border raids. The extent to which Mexico was a potential German ally against the U. S., and Imperial Germany's involvement in the Mexican problems on the border, is not generally appreciated today.

What is so striking in retrospect is the continuing role that WSL played in wireless intrigue even after its seizure by the U. S. Navy in 1915 [13, pp. 97-100; 14, p. 806]. The Zimmermann telegram went through Sayville, and diplomatic messages arranging munitions for Mexican revolutionaries on the California and Texas borders in early 1917 most likely routed the same. There is however, no provenance known for these messages beyond a German report after WW II. Herr Flicke, late of the Radio Intercept Service, reports a cable of 17 March 1917 from Zimmermann to the ambassador in Mexico: "Find out what ammunition and weapons are desired and what Mexican harbor on the east or west coast a German ship would enter under a foreign flag. As far as possible, Mexico must procure arms from Japan and South America." Flicke then reports the wireless response to Germany on 24 March: "The vice-consul in Mazatlan reports that Villa, who is being supported by the Germans, is expecting three shiploads of ammunition to be landed between Mazatlan and Manzanillo. . . " [5, p. 56]. The landing of arms in Mexico by German U-boats is also reported as the subject of the conspiratorial activities of a glamorous German lady spy in the United States by the name of Maria de Victoria [15, pp. 197-198]. However, "every German wireless message was being grasped out of the ether and read in Room 40" of the British Admiralty [13, pp. 7-8], including whatever went via Nauen in Germany and WSL at Sayville.

Mexico was the prize Imperial Germany wanted to tie up American warpower at the southern border and thus to keep the U. S. out of the European war that Germany hoped to win by attrition. Wireless played an important role in the game.

AMERICA'S WIRELESS COUNTERSPY

Wireless, and wireless interception, thus necessarily played a significant part in our relationships with both Germany and Mexico. Key to both was WSL. The station was, to some extent, what would today be called a proprietary asset of an intelligence service, in this case Germany's. In 1915, WSL was suspected to be transmitting to Germany, in coded form, information about allied shipping and other matters, in violation of the U. S. Neutrality Act [2, n. 6; 16, p. 16].

WSL transmissions were often very unusual, just a continuous sound rather than the usual Morse code dit-dah-dits. These transmissions were known to radiomen of the day as the "Nauen Buzz," after the main Telefunken station in Germany, call letters POZ. POZ operated with 100 kW on 6000 and then 12,000 meters, 50 kHz and 25 kHz respectively [17].

In normal service in 1915, WSL used a 1000-Hz quenched-gap spark transmitter operating at 35 kilowatts' power. It could radiate at wavelengths of 2000, 2500, 3000 or 4000 meters, with approximate frequencies of 150, 120, 100 or 75 kHz [17]. In 1915, WSL management claimed that it operated between 8000 and 10,000 meters, or 37 to 30 kHz, and other sources indicate that an alternator may have been the transmitter [19, 20]. The WSL quenched-gap transmitter had earlier, in 1909, been installed at POZ [17, p. 64]. The accompanying photograph of apparently the same transmitter at Sayville is from [18, p. 875].

Ed Sharpe of the California Historical Radio society (CHRS) notes that it has been suggested that the transmitter at Sayville was a Goldschmidt alternator, and therefore not the old Nauen 35-kW quenched gap, as later replaced by a Navy-installed 200-kW Federal arc [19]. Aitken reports the Sayville alternator to have been a comparable von Arco type rated at 100 kW, as of 1919 and possibly as early as 1914 [20, pp. 283, 326].

However, the photographs of the Nauen quenched gap of 1909 and the Sayville transmitter of 1915, as pictured then in connection with the seizure, closely match, as noted above. The transmitter as actually captured by Apgar on the surviving recording is clearly not an alternator; it sounds exactly like a 1000-Hz quenched gap as reproduced by the ARRL's George Grammer in his 1950s spark demonstration. Moreover, Wireless Age reported in 1915 [14] that the new Sayville transmitter went into service after the U. S. takeover of the station. Thorn Mayes [21] also concluded that Apgar recorded the quenched-gap transmitter.

Charles Apgar was a leading amateur radio operator of the day, with an interest in audio recording. He had recorded WSL as early as 1913, on an Edison disk recorder, and presented the disks to the station [18, p. 877]. The accompanying photograph of Apgar [22] shows him at his radio-receiving and cylinder-recording apparatus. Apgar described his apparatus and procedures in Wireless Age magazine at the time [23]. The schematic diagram of his receiver, which he described as an "Armstrong circuit [regenerative] valve detector," is from this article. According to a brief history in the museum of his home town, he is reported [24] to have called his receiving setup an "ampliphone" circuit. Per Matlack, Apgar used a $5.50 regular-filament McCandless audion. The acoustic coupling of the wireless receiver to the phonograph (a microphone amplifier) may derive from a 1911 article in Modern Electrics [25].

The U. S. government became interested in WSL's transmissions and the Nauen Buzz partly as a result of some investigative "yellow journalism" in early 1915 [16]. The Navy put observers into the station to determine if any activity violated the Neutrality Act. A copy of a Navy report on the station's operation in April 1915 [26] is included in this article.

Developing the first "data burst" technology, the Telefunken stations used an

No.

United States Navy Yard.

NEW YORK, N.Y.

APR 5 ... NAVY YARD, NEW YORK

Telefunken Radio Station.

April 4, 1915

Sayville N.Y.

From;Lieut.9JG) F. Cogswell.
To;Commandant Navy Yard New York N.Y.

Subject;Operations at the Sayville N.Y. Radio Station.

I respectfully state that during the preceeding twenty four hours,nothing has occurred of an unneutral nature as per Presidential proclamation,dated August 5,1914.

F. Cogswell

National Archives, New York branch.

early wire recorder, the Telegraphone, at fast and slow speeds. The stations transmitted their traffic at too high a rate to be copied by ear, reportedly by speeding up the rate of a transmitting Telegraphone keying the transmitter, but more likely by using available high-speed paper-tape keying equipment. The receiving Telegraphone recorded at the fast rate, but played back at normal speed. Apgar's Dictograph slowed down while he was replaying a transmission, and he realized it could be copied in this fashion as readable Morse code. He provided some 175 four- and six-inch wax cylinder recordings of the WSL-POZ transmissions to the Secret Service.

There is both contemporary and recent inference that WSL used a Telegraphone to key the transmitter at high speed. The evidence for this, however, is secondary or derivative. The strongest indication is "By 1922, the government was willing to admit that there had been at least one Telegraphone on which messages had been recorded in Morse code at standard speed. The tape [sic] was played at high speed, re-recorded in Germany, and played back at the original recording speed. There was no code to be broken after all" [27, pp. 42 and 45]. "The Sayville station * * * utilized * * * automatic transmission systems which used paper tape and piano wire (the latter system, in fact, was an American Telegraphone)." [28, pp. 27-28]. Kneitel, in his thorough article on the Sayville station [16, pp. 16, 18], says: "Sayville's transmissions [after routine traffic] became a strange chatter. This was the sound made by the telegraphone."

On the other hand, some knowledgeable people (including Bruce Kelley of AWA and Paul Bourbin and Ed Sharpe of CHRS) doubt that the Telegraphone wire recorder could key a powerful spark transmitter, by modulation or interruption. Signals detected off the air could surely be recorded as audio on a Telegraphone, and replayed more slowly, but there does not seem to have been a way to use the Telegraphone to transmit speeded-up copy. Sharpe points out that paper-tape keying was already very fast, citing Dr. Jonathan Zenneck. Zenneck was the station engineer at Sayville; his book [29] reports speeds up to 300 words per minute by paper tape keying, which must have been a buzz indeed. A speed of 100 WPM was common in Europe. In San Francisco, de Forest keyed an arc at 90 WPM with paper tape and received the result in Los Angeles with a Telegraphone recording the output of a tikker detector and audion amplifier [30]. De Forest's then-employer, Federal Telegraph, was connected with the Telegraphone's inventor, Valdemar Poulsen of Denmark, hence de Forest's access to the rare machine. Sharpe also points to an article about Sayville [31, p. 209] describing 24-contact keying relays transmitting at 150 WPM, keyed by perforated tape.

It is likely that Sayville used its Telegraphone to record the Nauen Buzz transmitted from Germany, and used paper-tape keying to transmit when it chose to send faster than monitors could copy by ear. Telefunken could well have inferred that its transmissions were monitored (as they were, by the Navy, at NAA, New York, and Fire Island, L. I.) Telefunken could also assume (until Apgar, anyway) that no such device as the Telegraphone was available, at least on the East Coast, to the monitors to slow down its transmissions to copy and decipher or decode them. The Telegraphone was an important secret communications instrument to Imperial Germany, found even on her submarines [27, p. 45]. Used in a submarine, the Telegraphone would permit large amounts of high-speed data to be acquired quickly during a short period on the surface.

So many years later, however, it is simply not known what steps were taken to disguise the true mode of operation of the Sayville station.

With Apgar's recordings on hand, the Government seized WSL on July 6, 1915, for violation of the Neutrality Act. Surprisingly enough, Telefunken had advance notice and had removed equipment, probably the Telegraphone, and presumably evidence, the night before [16]. WSL is presumed to have been sending information about Allied shipping to German naval forces for relay to submarines. This was the prosecution's charge against Dr. Zenneck at his trial. Presumably WSL had been the source of the information enabling a U-boat to sink the RMS Lusitania in May 1915 [16]. On the other hand, the Lusitania is now known (as a result of a secret cargo manifest reportedly found in President Roosevelt's desk) to have been carrying a cargo of munitions for England, also in violation of the Neutrality Act. After the Navy seized WSL, sinkings by U-boats declined substantially, and Zenneck is reported [24] to have been convicted on proof that U-boats picked up messages from WSL. Comparison of the traffic as filed at the station supervised by the Navy censors with the traffic as recorded by Apgar is reported there to have disclosed at least sufficient discrepancies to justify seizure. As mentioned before, at least some submarines carried Telegraphones and could have copied the "Buzz" quickly on the surface, then submerged for a more leisurely analysis of target data.

Apgar got considerable good press for his work as America's first Radio Counterspy, within days of the seizure of the station. His work was later hailed as "the most valuable service ever rendered by a radio operator to this country" [32]. However, doubt has occasionally been expressed that even the Secret Service could have quickly enough penetrated any code or cipher used by WSL. All the evidence nonetheless points to Apgar's work as being instrumental in disclosing non-neutral and violative transmissions of WSL to POZ [31, p. 210]. Matlack is definitive that Apgar's work exposed non-neutral activity.

On the other hand, intelligence agencies love cover stories, red herrings, and disinformation. What it was, exactly, in the WSL transmissions that violated the neutrality laws is not clear. It has, however, since become known that an Allied spy appearing loyal to Germany had been placed in the station itself and helped to operate it. A spymaster named Emanuel Voska (code-named "Victor"), working for the British, had placed agents throughout Germany's assets in the U. S. in 1915: "one was an operator at the Sayville wireless station on Long Island, which was used by the Germans for communications overseas." [13, p. 71]. Voska wrote a book of his own after the war; a recent history of American espionage [15, pp. 188 ff.] details his exploits, including the plant at Sayville.

At this remove, it is not known if WSL was seized *because of* violations of the neutrality laws or *to prevent* violations. Apgar reports in the 1934 interview that Radio Inspector Krum assured him that his work was instrumental to the seizure. Yet perhaps this was so because it provided a likely story for a preemptive and illegal interference with a legitimate commercial communication facility. Exactly who did what to whom, as usual, is lost in what the late James Jesus Angleton, late of the CIA as its Chief of Counterintelligence, once called the "wilderness of mirrors."

WSL continued in operation under the aegis of the Navy, soon with the call letters NDD [33]. A copy of a July 28, 1915, Navy memorandum [26] outlining the procedures is reproduced with this article. The station continued to carry supposedly commercial traffic to Germany, at least until the declaration of war intervened in April 1917 [14, pp. 807 ff.; 20, p. 285].

It is one of the ironies of history that the Navy thus oversaw the transmission of the hostile Zimmermann telegram from Germany to the German Ambassador in Mexico City via Sayville on January 16, 1917. According to the German Flicke, the best source [5, pp. 48 ff.], "This telegram was so important that * * * several routes were chosen * * * [t]he first led via radiotelegraphy from Nauen to Sayville on Long Island for forwarding to the German Ambassador * * * in Mexico." The story from the German perspective is that the Foreign Office also snookered the American Ambassador in Berlin into conveying an enciphered copy of the telegram to the German Ambassador in Washington. The British Wireless Intercept Service in MI6 and Admiralty Room 40 partially decoded the Nauen-to-Sayville radiotelegram, and fully decoded the text sent via the American Ambassador. The British were delighted to hand it over to the Americans, claiming they stole it from the telegraph office in Mexico City [8, pp. 88 ff.; 13].

Apgar's work protecting the U. S. ether in 1915 has its exact analog in protection of American computer networks (known as "cyberspace") by another gifted amateur, Clifford Stoll, in 1987. He intercepted and eventually effectuated the capture of a West German computer hacker and KGB agent who had penetrated the U. S. military and civilian networks [34].

AMERICA'S FIRST WIRELESS SPIES

At the same time in early 1917, Germany supported and encouraged Villa and Cantu, another Chicano revolutionary said to be operating in Southern Califor-

```
Copy to Mr. Collins                                    #2396-ID/MA


#161783-855W                 NAVY DEPARTMENT,
                     BUREAU OF STEAM ENGINEERING,
                          WASHINGTON, D.C.
                                                   July 28, 1915.
From:   Bureau of Steam Engineering,
To:     Commandant, Navy Yard, New York

SUBJECT:  Radio Station Sayville placed under Navy Yard, New York,
            for maintenance.

  1.  In accordance with paragraph 4103 U.S.Naval Instructions the
Radio Station, Sayville, is placed under the cognizance of the Com-
mandant, Navy Yard, New York, for supply, while the Sayville station
is under the control of the U.S. Government.
  2.  This includes only extra supply of material necessary, due to
the addition of Navy personnel at Sayville.
  3.  The Officer-in-Charge will, when the station is eventually
turned over to its owners, return all Navy material to New York.
  4.  The owners are maintaining the station in operating condition.
                                          Griffin
#560-5   Commandant's office   July 29/15.  To: GSK For inf & return.
                                          Upham By direction GEB

1401-20           2nd indorsement  Mc D/CFD-AS  Aug.3/15.
From: Eng.Off, To: Comdt Via: A.O. GSK.
  1.  Returned; contents noted.
   2. Job order 3 S 312/15 has been issued.
                                        R.B.Dungan, Acting
B-150 (7-5-F)      4th indorsement  Aug.5/15. From:AO To:Cmdt via GSK
1.  Returned; contents noted.



                         5th endorsement,
#2596 ID/MA                              Navy Yard, New York,
                                                   August 6, 1915.

From: General Storekeeper.
To:   Commandant.

    1.  Returned; contents noted.

                                       C.C.TOBEY
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National Archives, New York branch.

nia. British MI6 and Room 40 intercepted and decoded German diplomatic radio traffic arranging shipments of munitions for the revolutionaries, who also continued to threaten the U. S. border. As noted previously, a reliable German wireless history reports a wireless telegram on March 24, 1917 to Germany dealing with provision of arms to the revolutionaries.

In the American military operations into Mexico of the prior year, wireless and wireless spying played crucial roles. The Signal Corps and the Military Intelligence Division became America's first Wireless Spies. They operated out of horse-drawn wagons and motor trucks. "Radio Tractors" of two types were commissioned in 1914 [35]. Their spark transmitters were of either one or two kilowatts in power, for ranges up to 300 miles. Wireless was used extensively to supplement Army single-wire telegraph circuits, and to report back to the

United States. (A romantic fascination with border intrigue persisted for some time; see, for example, The Radio Boys on the Mexican Border [36].)

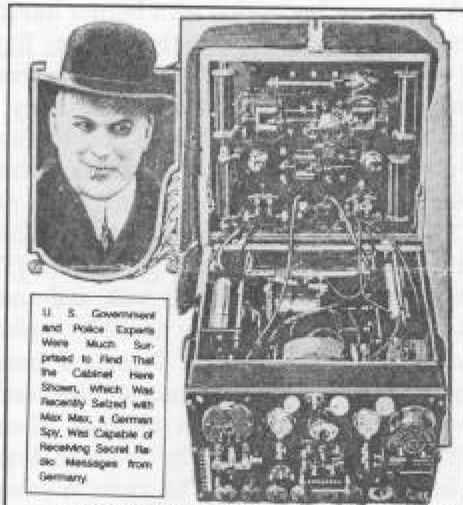
As early as the winter of 1914-15, Germany had aggravated U. S. - Mexican friction by planting rumors of a hostile Japanese army in Mexico, using the wireless of the imperial cruiser Geier while in port in Pearl Harbor [13, p. 55]. There was some physical evidence of an armed Japanese reconnaissance into Arizona [15, p. 181]. German wireless operators were running Mexico's main receiving station [13, p. 66]. Germany had a secret wireless station in Mexico as late as 1918, ferreted out by an American spy in April [37, p. 123]. The press frequently reported German spy stations as well, and noted the capture of spy Max Wax with his well engineered receiver in 1917. A picture of Herr Wax and his radio [38] accompanies this article. Robert Johnson of CHRS has researched press reports from 1917 of German wireless activity in Mexico at the San Jose (CA) Mercury-News, finding such stories as "German Officers, Many in Tijuana; Three Wireless Plants Operated by Teutonic Army Men in Lower California" (dateline San Diego, March 2); "Mexican Wireless Reaches Germany" (Washington, March 8); "Secret Wireless on German Vessel" (Norfolk, VA, March 9); and "German Spies Are Rounded Up By U. S." (New York, April 7). The latter reports: "Until a few weeks ago a wireless receiving plant of the most expensive type was operated on the roof of [a] Fifth Avenue home." This set was operated by the butler, of course.

One can detect a certain amount of war hysteria in these reports. On the other hand, Telefunken engineers did escape Sayville and set up a wireless station at Chapultepec to communicate with Nauen [20, p. 286, n. 50]. Haraden Pratt, working for the Navy in 1917, triangulated this station from San Diego, Phoenix, and El Paso as being located in Mexico City. He reports it [39] as a 100-kW spark-gap set smuggled in from Nauen.

With whatever German support or connivance [37, p. 93], "Pancho" Villa raided Columbus, New Mexico, killing 17 Americans, on March 9, 1916. General "Black Jack" Pershing, already at the Texas border, invaded Mexico on March 18. Two days after the incursion by Pershing "there arrived the first direct news by wireless from our Army in Mexico, telling the whereabouts of the bandits who had perpetrated the massacre" [35, p. 751].

The report of Wireless Age that "Villa was located by radio" could have meant that his approximate location was reported out of Mexico, or that the Signal Corps located him by wireless interception. Villa, however, did not have wireless equipment. His hostile fellow revolutionary, Venustiano "Don Venus" Carranza, was the most recent government, and his forces did use wireless. Looking for Villa, the Signal Corps radio tractors monitored the Carranzistas, in America's first military use of technical intelligence [40, p. 13]. (Carranza retains sufficient respect in present-day Mexico to appear on the obverse of the 1984 100-peso coin, looking like a wooly-bearded Teddy Roosevelt.)

The Signal Corps and the Military Intelligence Division also set up monitoring stations along the border as early as 1916. They wanted to listen to German activity as much as to Mexican. The accompanying photo of the receivers in one such station is from 1918 [40, p. 23]. The program of interception was very successful, although the product has been declassified only recently, 70 years later. The early Mexican intercepts were declassified as a result of New Mexico State

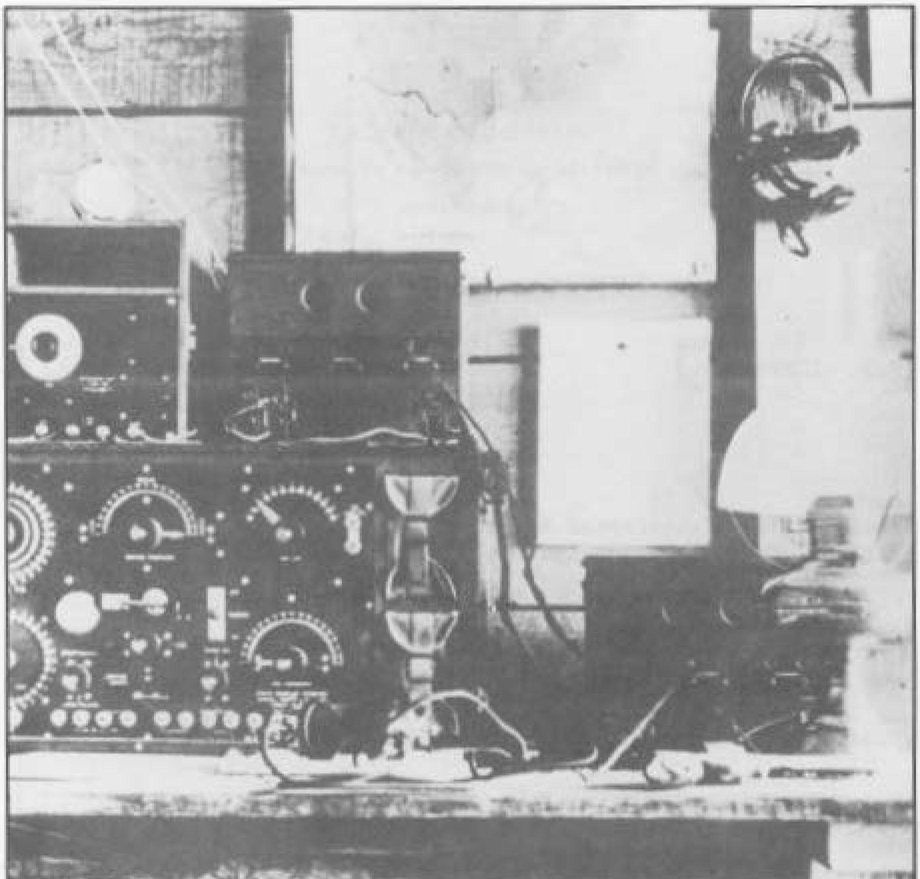


Electrical Experimenter, June 1917.

University professor Ray Sadler's request under the Freedom of Information Act in researching his book on border history [37].

The Signal Corps receiver at the monitoring station is in the style of National Electric Supply Company (NESCO) equipment, using a horizontal, external cats-whisker galena or silicon detector. Will Jensby of CHRS identified it as a "Cohen Type A" Signal Corps Static Coupled Receiver. A similar set is pictured in Vintage Radio [41]. The white circle to the left of the detector arm that looks like tube glow through a porthole is actually a buzzer. The receiver also appears to be accompanied by possibly two, two-tube audio amplifiers (the boxes with dark portholes). The receiver's nomenclature is STATIC COUPLED RECEIVER/SIGNAL CORPS U. S. ARMY/ . . . APRIL 26, 1916. It has a rotary switch for SHORT WAVES, MEDIUM WAVES and LONG WAVES just beneath the detector arm, a vertical white on-off switch for BUZZER, and a half-circle face for COUPLING CONDENSER just above the detector arm, along with the rotary inductance taps for LARGE PRI. COIL and SMALL PRI. COIL.

The Signal Corps equipment was certainly as good as or better than the Mexicans' receivers, which had a night range of half a continent. So reported Wireless Age magazine in 1915. A Carranza opponent had two portable wireless sets in Merida, and established a fixed station. His transmitting power was 1.5 kW. He noted "I was able to receive 800 miles during the daytime and 1500 miles at night" [42]. Pershing's forces used the mobile Radio Tractors to listen for word of Villa from the Carranzistas [40, p. 13]. Accompanying this article are reproductions of two Mexican intercepts [43] from the Signal Corps Radio Tractors still in use at Pecos and McAllen, Texas, in May 1919. A brief moving picture, circa 1918, of such a Radio Tractor in operation, probably in France, with about a seven-foot square multiwire loop antenna on top, appears in the PBS television series on U. S. intelligence aired recently. (The Army's new Bradley Fighting Vehicle reportedly will also be fitted out as a modern-day Radio Tractor.) As identified by Matlack, the upper Radio Tractor pictured is a Jeffrey four-wheel-drive vehicle in the style of a Dodge truck. The second vehicle, shown in a field



Army photo of Mexican Border intercept station, 1918.
Courtesy of Cloak and Dagger Publications, reproduced by permission.

in Texas, is a solid-tire White truck manufactured in Cleveland.

For its own communications as well as intercepts, the Punitive Expedition in 1916 also used horse-drawn Radio Wagons, each with two carriages, on the model of the caisson and limber of the field artillery. Such radio wagons are depicted under construction, in photos from the collection of CHRS founder Norm Berge. The contemporary legend on the photos is "Radio Wagon Set 2 KW 500 [Hz] Instrument cart under construction 2-1-18." One carriage held the generator unit and the other the radio equipment. A Wireless Age cover photo [35] shows a Signal Corps radioman operating just such a receiver and transmitter at the rear of an Instrument Cart.

The U. S. Army bought its first radio wagons from Telefunken in 1910, two-kilowatt, 500-Hz quenched-gap transmitters operating between 500 and 2000 meters [44]. In 1913, the Army had purchased British Marconi wireless-telegraphy cart stations of the "F" type with a power of 1.5 kW and a 200-mile range. (See the "New Wireless Pioneers" reprint of a 1913 item and photo from The Weekly Marconigram produced for a recent Army exhibit, described in [45].) Marconi had had a steam-powered wireless truck operating as early as 1900, with

WAR DEPARTMENT

OFFICE OF THE CHIEF OF STAFF

WASHINGTON

C.B. 10898 W.D. 65-33D 2242

May 21st, 1919.

Radio message intercepted by Tractor Unit No. 33,
McAllen, Texas, May 2d, 1919.

From Unknown

To Unknown

Message with cipher numerals 28 21 32 31 24 13 etc.

DECIPHERMENT:

-----vinieron mas cuatrocientos hombres----ayer partido llamado socialismo Yucatan recorieron calles lanzando injurias y gritos susersivos contra este gobierno. Policia mantuvose prudente sin interrumpir manifestacion. A continuacion reunieronse meeting en balcones hotel frente plaza principal. Hablo coronel---orden luego Santiago Hernendez injuriando personalidades partido contrario invitando publico derrocar bandidos ocupan gobierno etc.

TRANSLATION:

-----more than 400 men arrived----yesterday of the socalled Socialist party. They paraded thru the streets shouting insults and indecent things against this government. The police were prudent and did not interfere with the manifestations. The party afterwards held a meeting and from the balcony of the hotel opposite the main square colonel spoke---Immediately thereafter Santiago Hernendaz insulted the chief members of the opposition parties, inviting thepublic to oust the bandits who at present hold the government etc.

National Archives, #RG457.

WAR DEPARTMENT

OFFICE OF THE CHIEF OF STAFF

WASHINGTON

[G.B. 10900 W.D.] [6543D 2470]

May 21st, 1919.

[Radio message intercepted by Tractor Unit No. 43, Pecos, Texas, May 2d, 1919.]

From J.Mucel

To Unknown

[Message with Cipher Numerals 10 31 24 33 20 etc.]

Mimeo. pl.

[DECIPHERMENT:]

----que conducto debe observarse con elementos Tucatecos algunas armados que en mas vengan a verificar hechos como el presente policia recogio distintivos y tarjetas identificacion son da lisdad Tucatecos agradecerle tambien de sirva ordenar se recuerde a la guarnicion el contenido de los articulos quinientos cuarenta y cinco, un mil trece, un mil diecisiete y un mil dieciocho de la ordenenza general del ejercito y ciento quince y ciento veintenueve constitucion general republica.

[On may 2, J. Mucel, location unknown, sent following to unknown address:] TRANSLATION:

---[what action should I take with Tucatanians! Some of them are etmed and might gather in large crowds and commit acts like the one described. Police has taken up the badges and identification cards with lists of Tucatanians. I will be obliged if you will issue orders to have the attention of the garrison called to the contents of articles 540, 1013, 1017 and 1018 of the general army code and 115 and 129 of the constitution of the republic.]

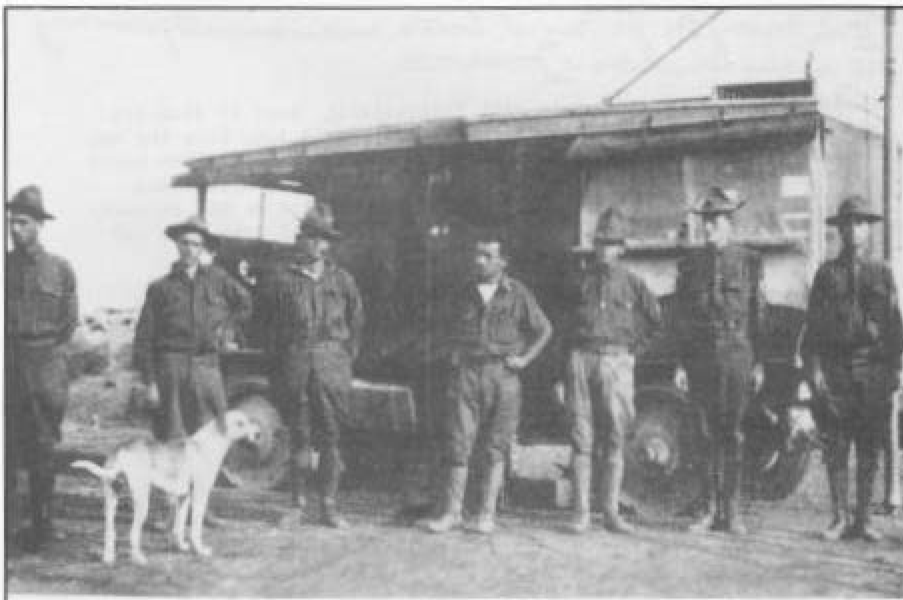
J.Mucel.

National Archives, #RG457.

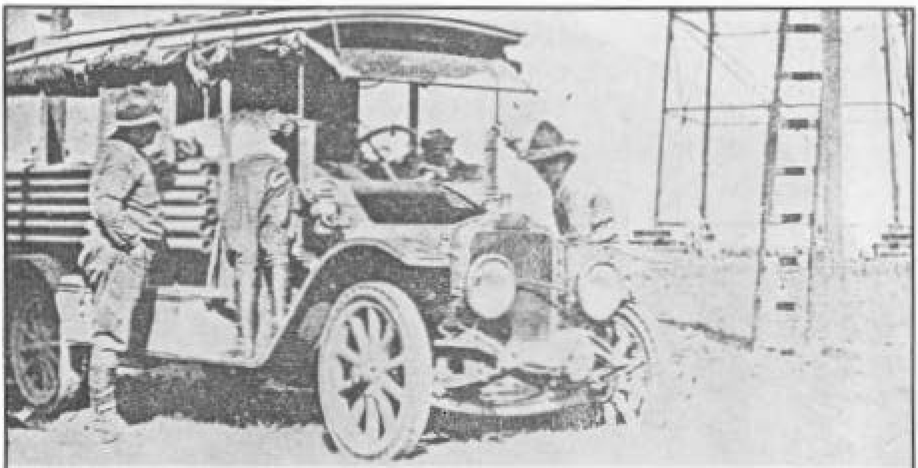
a 20-mile range. (This truck is illustrated and described on a 1901 color English cigarette card, Lambert & Butler Wireless Telegraphy set, Card No. 9, in the author's collection.)

The receiver in the Signal Corps radio wagon is a crystal detector with a catswhisker on a horizontal arm. The labels on the rotary inductance taps across the top of the set read (left to right): LARGE PR COIL, SMALL PR COIL and SEC COIL. The two half-circle dials on the far left and far right read COUPLING CONDENSER and SECONDARY CONDENSER respectively. The catswhisker arm is horizontal between two white vertical lever switches, the left one reading BUZZER. There are two rotary switches beneath the white vertical switches.

"Radio Tractor" at Ft. Myer, Virginia, 1914 Army photo.

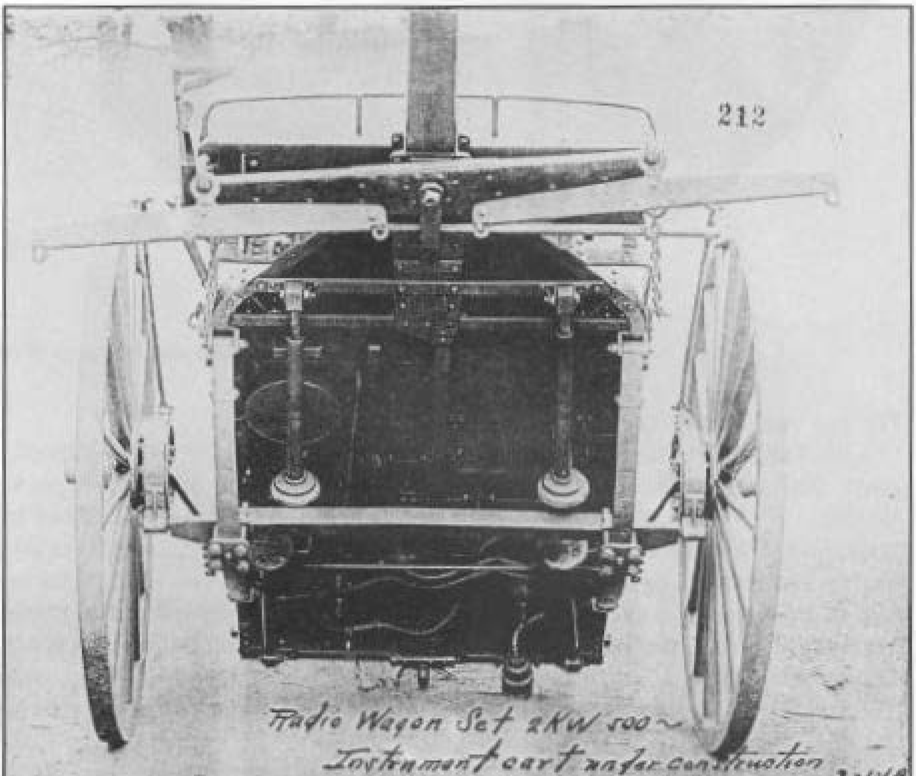


"Radio Tractor" in Mexico, 1916 Army photo.
Courtesy Cloak and Dagger Publications, used by permission.



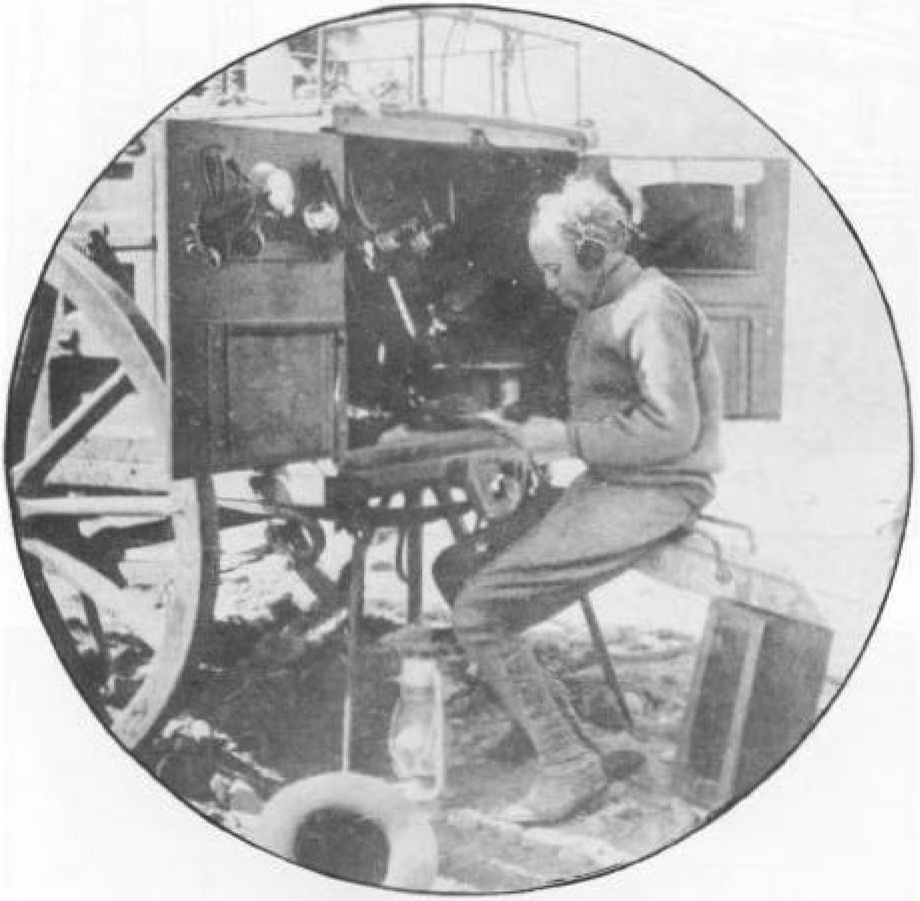
Another radio truck being equipped for use in Mexico.

Wireless Age, Aug. 1916, p. 756



Trailer set being built.

Photo: Collection of Norm Berge.

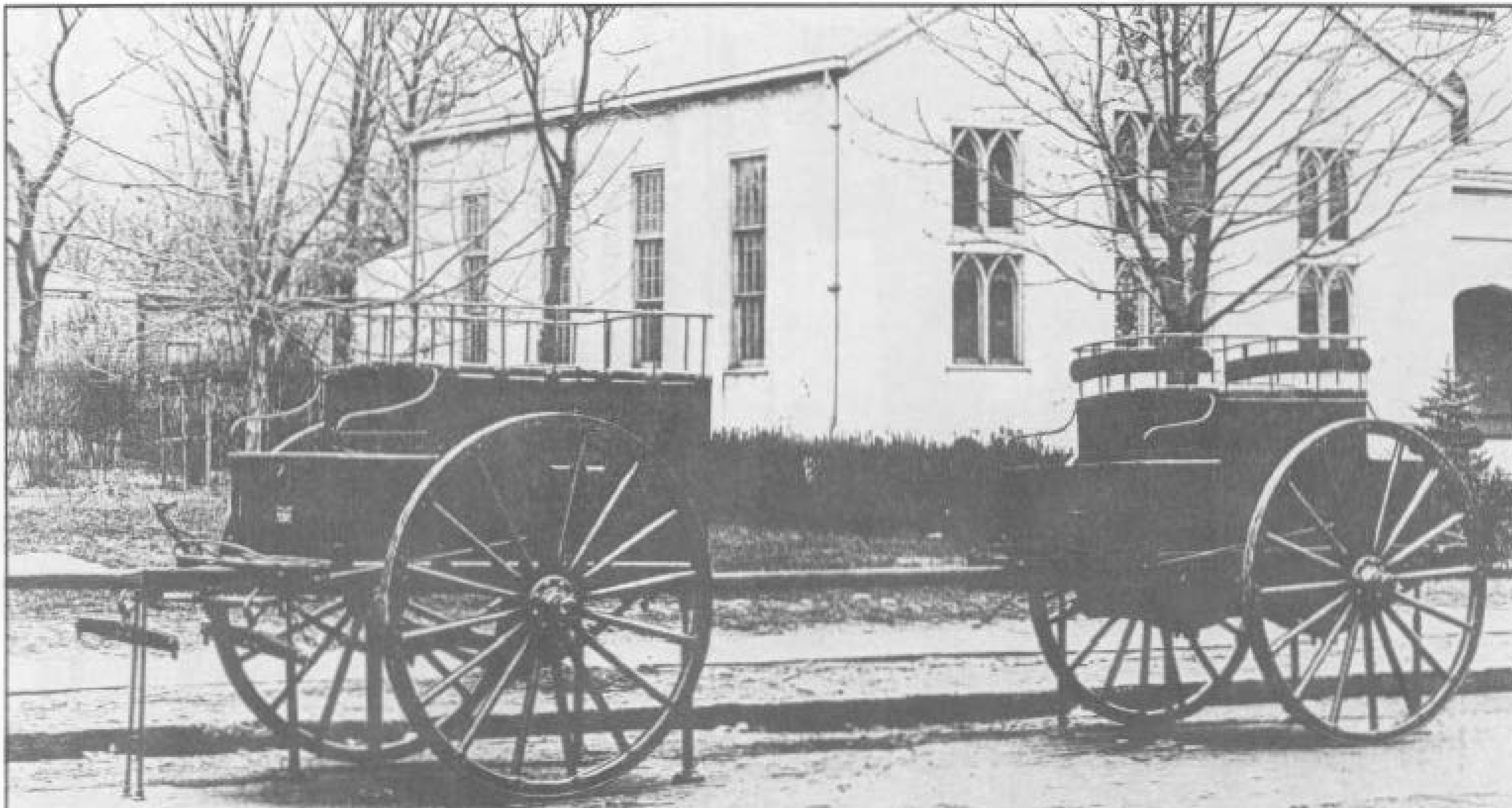


Trailer set in use in Mexico.

Wireless Age, August 1916

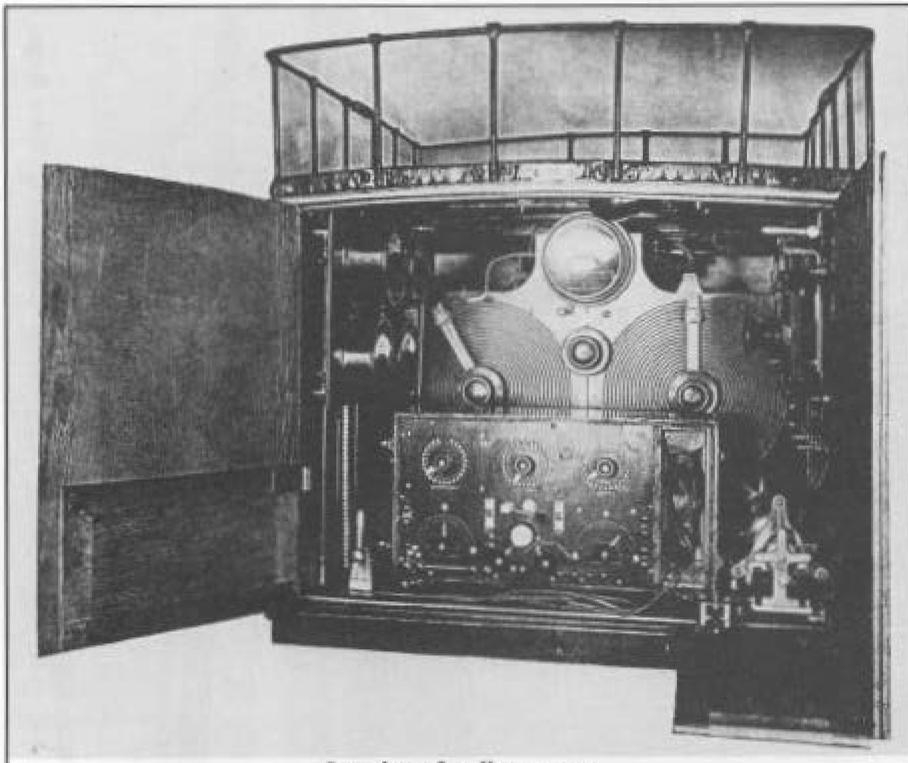
The one on the right reads SECONDARY TUNED/UNTUNED.

In the fall of 1916, after Villa's raid and the U. S. response, the Military Intelligence Division and the Signal Corps were routinely doing radio intercepts in Mexico. They had established a chain of about a dozen intercept stations by early 1918. Stations were located at Fort Bliss and both Radio Tractors and wagons had gone along with Pershing's forces, according to Prof. Sadler. An article in Wireless Age also notes, with regard to the 1916 period: "The Signal Corps at Marfa [Texas] had a small unofficial radio receiving station which was capable of receiving from Juarez, in Mexico" [46]. George Sterling has reported [47] that these intercept stations also appeared at Las Cruces, NM (operated by Clarence Pfeifer, later W2FG) and at Ft. Sam Houston, TX (operated by Conrad Sedlack). Mr. Sedlack intercepted part of the Germany-to-Mexico traffic relating to Mexican participation in WW I, and also Japanese Kana code traffic. By October 1918, the U. S. had a transatlantic intercept station operating in Maine listening to Europe [1, p. 5], with Mr. Pfeifer as one of the operators.



Signal Corps radio wagon.

Photo: Collection of Norm Berge.



Interior of radio wagon.

Photo: Collection of Norm Berge.

Radio intercept capability had entered the American intelligence arsenal.

CONCLUSION: FROM WIRELESS INTRIGUE TO MODERN SIGNALS INTELLIGENCE

Before and during the First World War, wireless intercepts played an important role in informing America about the intentions and activities of Imperial Germany as a European belligerent with hostile intent, and about Mexican factions as potential German allies. Every art advances other arts and, of course, every weapon leads to a defense against it. Wireless was no different in its early days. As soon as wireless was put to use against American interests as a tool of espionage in 1915, Charles Apgar exposed it: America's first Wireless Counterspy. As soon as wireless appeared useful to American forces in gathering intelligence, the Signal Corps and the Military Intelligence Division employed it, in 1916: America's first Wireless Spies. The resources and procedures of the NSA, and the intercept services of the CSS and the armed services, all derive from these early and effective American efforts.

NOTES AND SOURCES

This article in an early form was a companion paper to the CHRS Radio News Audio Journal Special Edition of November 1988, "The 1915 WSL Sayville Spark

Transmissions and George Grammer W1DF Spark Demonstration" and of March, 1989, "NBC Broadcast Interview with Charles Apgar, 1934, About Recording the Sayville Station in 1915." Copies of both these tapes, containing the only known recordings of pre-WW I spark transmitters in service (WSL and WHD) are available from CHRS through the author (327 Filbert Steps, San Francisco, CA 94133).

The text of the recorded 1915 WSL transmission is "R84 TEMP 54 NORTHWEST CLEAR 34 MILES ?? BAR 29R84 TEMP 54 NORTHWEST CLEA" (per Dick Dillman, N6NV). The text of the 1915 WHD transmission is "MNY K BT INVESTIGATION SHOWS MISSING BANK CLERK HENRY BRADLEY MERCHANTS NATL BANK SHORT HUNDRED FIFTY THOUSAND PLAYED RACES PLUNGED STOX" (per James Maxwell, W6CF). Radio station WHD is said in the interview to have been owned by the New York Herald newspaper. As early as 1910 the Herald operated a 2-kW Fessenden-system transmitter on 945 meters with a 1000-mile range, using the call OHX [48]. (The call letters WHD are, however, listed to the New York City Fire Department in the 1913 U. S. Government Callbook, Supp. #2, OOTC Ed., and much later to the New York Times.)

The recordings reproduced by CHRS were located in the AWA Museum archives by curator Bruce Kelley, who took the Apgar WSL recording off a 1934 transcription of the broadcast interview. The spark signals had been acoustically transferred from Apgar's original Edison Dictagraph wax cylinders to the recording of the interview. The 1934 interview, including the WSL-WHD recordings from 1915, comes to CHRS most directly from a tape courtesy of Robert Angus. Part of it appeared as a tipped-in phonograph-record "sound sheet" accompanying [28, p. 32].

The original interview by NBC announcer George Hicks was broadcast on December 27, 1934, on NBC's station WJZ in New York, on the occasion of the opening of its museum of radio (since dispersed). It was recorded on four sides of two vertically cut aluminum disks. Lawrence Apgar gave the disks to Rexford Matlack, who presented the recordings of the interview to the AWA Museum in 1976 [49] along with a master tape he had made of them. CHRS continues its quest for off-the-air recordings of spark transmitters. Inquiries continue as to the whereabouts of Apgar's 1915 cylinders, if indeed they survive. Information leading to these or other off-the-air recordings of spark transmitters will be greatly appreciated.

ACKNOWLEDGMENTS

My errors are my own, but only with the help and encouragement of the following people has this Note come together in its present form. Grateful and alphabetical thanks to: Robert Angus for the tape of the 1934 Apgar interview; Norm Berge, CHRS, for the Radio Wagon photo; Paul Bourbin, CHRS president, for his encouragement and for authorizing publication by CHRS of the first version of this material and issuance of the Special Edition of CHRS Radio News with the 1915 Apgar recordings of WSL and WHD and his interview; David Dintenfass, Puget Sound Antique Radio Association and Northwestern Vintage Radio Society, for his note "Sound Recording on Magnetic Wire: A

Selected Chronology," and copies of Angus articles; Bill Helandes, CHRS, for the "Old Towne Scrapbook" material on Apgar; Will Jensby, W0EOM, for source material including the Pratt manuscript; Robert Johnson, CHRS, for researching the WW I press reports about Mexican revolutionaries and German wireless operations; Bruce Kelley, W2ICE, for the 1915 off-the-air recording of WSL in service, and for permission to reproduce the 1934 Apgar interview; Rexford M. Matlack, for the provenance of the Apgar recordings, a copy of his "73" article and much information with the pleasure of a long talk at the 1989 AWA conference; Ray Sadler, professor of history, NMSU, for numerous sources and much detail on intercept operations in connection with Pershing's expedition; Anthony Santossi, National Archives, New York Branch, for the Navy documents regarding WSL; Ed Sharpe, CHRS, for numerous sources and considerable insight and analysis; Elliot Sivowitch, Smithsonian Institution, for George H. Clark materials and the lead to the Apgar recording; John Taylor, National Archives, Washington, DC, for first information on the 1916 wireless intercepts associated with Pershing's expedition and the copies thereof; A. G. "BB" Wentzel, Jr., W2HX, for the Apgar stories in Wireless Age; and Dale Winn, Cloak and Dagger Publications, for permission to reproduce photos from its copyrighted edition of Military Intelligence, A Pictorial History.

REFERENCES

1. Bamford, J., The Puzzle Palace (Boston: Houghton Mifflin Co., 1982).

2. Matlack, R., "The Quiet Spy - Amateur Uncovers Spy Ring in US!," 73, Nov. 1976, p. 188.

3. "The Radio Month - Charles E. Apgar," Radio-Electronics, October 1950, p. 12.

4. Lessing, L., Man of High Fidelity: Edwin Howard Armstrong (New York: Lippincott, 1956; Bantam Ed., 1969) p. 56.

5. Flicke, Wilhelm F., War Secrets in the Ether (Washington: NSA translation, 1954). The book has reportedly been reprinted by the Agean Press in the Los Angeles area.

6. The History of U. S. Electronic Warfare (Society of Old Crows, 1987), pp. 4-5.

7. Kahn, D., "Codebreaking in World Wars I and II," The Historical Journal, Vol. 23, No. 3 (1980), pp. 617 ff.

8. West, N., The SIGINT Secrets (New York: William Morrow & Co., 1988).

9. Vermeulen, D. J., "Wireless in the South African War," AWA Old Timers' Bulletin, Vol. 31 No. 1 (May 1990), p. 32.

10. Aitken, H. G. J., Syntony and Spark (Princeton, NJ: Princeton University Press, 1985).

11. "The Law and Wireless Amateurs," Modern Electrics, Vol. 4, No. 9 (Dec. 1911), p. 641.

12. Wright, P., Spycatcher (New York: Dell, 1988), p. 10.

13. Tuchman, B., The Zimmermann Telegram (New York: Ballantine, 1979).

14. "The Seizure of the Sayville Station," Wireless Age, Vol. 2 (NS) (Aug. 1915).

15. Miller, N., Spying for America (New York: Paragon House, 1989).

16. Kneitel, T., "Germany's High Power Spy Station - in the USA!," Popular Communications (Oct. 1984).

17. Goodnow, A. C., "Across the Gap: An Appraisal of Spark Radio Telegraph Engineering," AWA Review, Vol. 2 (Holcomb, NY: Antique Wireless Association, Inc., 1987), pp. 21 and 60-66.

18. "A Wireless Detective in Real Life," Wireless Age, Vol. 2 (NS) (Sept. 1915), pp. 872-73.

19. "Arc, Not Alternator, or Both?," AWA Old Timer's Bulletin, Vol. 17 No. 1 (June 1976), p. 28.

20. Aitken, G. H. J., The Continuous Wave: Technology and American Radio, 1900-1932 (Princeton, NJ: Princeton University Press, 1985).

21. Mayes, T., Wireless Communication in the United States (East Greenwich, RI: New England Museum of Wireless and Steam, 1989), p. 125.

22. Popular Radio, November 1923, p. 349.

23. Apgar, C., "Making the Records from Sayville," as [18], p. 877.

24. "Wireless Wizard Out-Wits German Spies," Olde Towne Scrapbook, p. 91.

25. Gradenwitz, A., "A Novel Tele-Phonograph," Modern Electrics, Vol. 4, No. 4 (July 1911), p. 224.

26. National Archives, New York Branch, various naval documents.

27. Angus, R., "75 Years of Magnetic Recording," High Fidelity Magazine (Mar. 1973).

28. Angus, R., "History of Magnetic Recording," Audio (Aug. 1984).

29. Zenneck, J., Wireless Telegraphy (New York: 1915), p. 203 and Note 2 on p. 302.

30. Carneal, G., A Conqueror of Space - An Authorized Biography of the Life and Work of Lee de Forest (New York: Liveright, 1930), p. 243.

31. "Why Sayville Radio Station Was Closed," The Electrical Experimenter (Sept. 1915).

32. DeSoto, C. B., 200 Meters and Down: The Story of Amateur Radio (West Hartford, CT: American Radio Relay League, 1936; 1981), pp. 44-45.

33. Kneitel, T., Radio Station Treasury (Commack, NY: CRB Research, 1986), p. 17.

34. C. Stoll, The Cuckoo's Egg - Tracking a Spy Through the Maze of Computer Espionage (New York: Doubleday, 1989).

35. "The Epic of the Mexican Border," Wireless Age, Vol. 3 (NS) (Aug. 1916), cover and pp. 750 ff.

36. Breckenridge, G., The Radio Boys on the Mexican Border (New York, A. L. Burt Co., 1922).

37. Harris, C. & Sadler, R., The Border and The Revolution (Las Cruces, NM: New Mexico State University Press, 1988), p. 93.

38. Electrical Experimenter, June 1917.

39. Pratt, H., "Sixty Years of Wireless and Radio Reminiscences," unpub. ms. in the Per-

ham Foundation collection, Foothill Electronics Museum, Los Altos Hills, CA, p. 18.

40. Finnegan, J. P., Military Intelligence, A Pictorial History (U. S. Army Intelligence and Security Command, 1984; reprinted 1988 by Cloak and Dagger Publications, P. O. Box 53, Hooper, Utah 84315).

41. Greenwood, H. & McMahon, M., Vintage Radio (Palos Verdes, CA: Vintage Radio, 3rd Ed., 1981), p. 63.

42. Urcelay, F., "The Wireless Age in a Revolution," as [14], pp. 812-13.

43. Border intercepts, National Archives #RG457.

44. DeCelle, O. A., "New Military Quenched Spark Set," Modern Electrics, Vol. 3, No. 9 (Dec. 1910), p. 508.

45. Kreuzer, J., "Marconi Visits the U. S. Army Show," Antique Radio Classified, Jan. 1990, pp. 18-19.

46. Rose, Sgt. F., "Before We Go Overseas," Wireless Age, Vol. 5 (NS) (July 1918), p. 811.

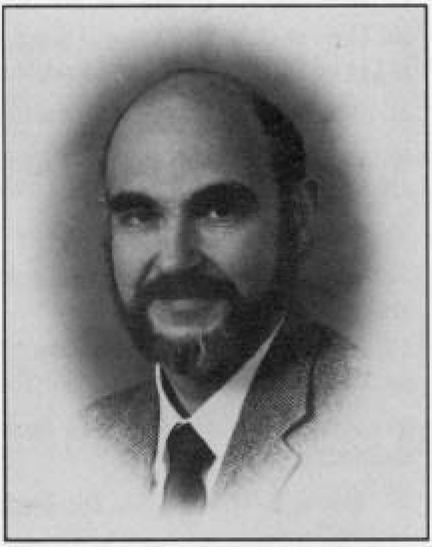
47. Sterling, G. E., "Some Experiences in Radio Intelligence and Counter Espionage," OOTC Spark Gap Times, No. 14, April 1, 1963, p. 3.

48. Modern Electrics, Vol. 3, No. 7 (Oct. 1910), p. 381.

49. "Rare Recordings," AWA Old Timers' Bulletin, Vol. 16, No. 4 (Mar. 1976), p. 30.

Bart Lee

Bart Lee is an attorney by trade, specializing in transnational and complex litigation, as well as special counsel for the Perham Foundation Foothill Electronics Museum and the California Historical Radio Society (of which he is also vice president). He has long enjoyed listening to, building, and more recently restoring, collecting and writing about, radios and radio history. When not lawyering, teaching and actively raising a family, he also likes to monitor utility, broadcast and specialized communications, longwave to two gigahertz, from the radio shack at home and from wherever in the world he may find himself.



THE TRIODE THAT PREDATED DE FOREST: ROBERT VON LIEBEN AND THE LRS RELAY

Thomas H. Briggs IV

INTRODUCTION

A triode amplifier tube with alkaline-earth oxide emitter, patented before de Forest's Audion detector tube? An amplifier tube in production before Western Electric made any of Arnold's improved high-vacuum triodes? This is the story of the von Lieben or LRS tube, which performed both of these remarkable feats. The man responsible, the evolutionary steps, the surrounding circumstances, all join in the story of a development deserving to be known far better in North America.

The electron-tube industry sprang from three design directions that formed the basis of early production. They were: 1912-20, the von Lieben mercury-vapor triode; 1913+, the de Forest/Western Electric/General Electric vacuum triodes; 1915-23, the French military "TM" high-vacuum triode.

Robert von Lieben obtained German patent DRP Nr. 179,807 for a triode amplifier device. His application was filed on March 4, 1906, and the patent was published November 18, 1906. By contrast, Lee de Forest's Audion did not operate in his laboratory until December 30, 1906. His famous patent application, filed January 29, 1907, was issued as U. S. Patent 879,532 on February 18, 1908.

Unlike de Forest, von Lieben continued major development work which resulted in commercialization in 1912 of a structure far different from that of 1906. Von Lieben's tube performed as an amplifier from the very start. The interests, and hence the goals, of the two inventors were markedly different. Von Lieben had no contact with wireless, only with wire telegraphy and telephony. Only amplification was required. In contrast, de Forest was thoroughly immersed in wireless in all its phases. Consequently it is astounding that he and others neglected his "detector" audion for six years before attempting to develop its other characteristics as an amplifier and oscillator.

There were fundamental differences between the von Lieben and de Forest tubes. Advocates of either type might well cry out: *vive la différence*!

Figure 1 illustrates the initial commercial form of the LRS tube in 1912. It was about 17 inches (43 cm) high. The bulb, pinched in at its center, confined the planar woven-wire mesh grid. In operation the tube was spectacular: The bottom half glowed red from the large-area oxide-coated platinum filament; the top half was filled with a sky-blue glow of ionized mercury vapor.

THE MAN

Robert von Lieben was born on September 5, 1878. He was not the usual penurious inventor living in a garret. His father, Leopold, was a wealthy banker

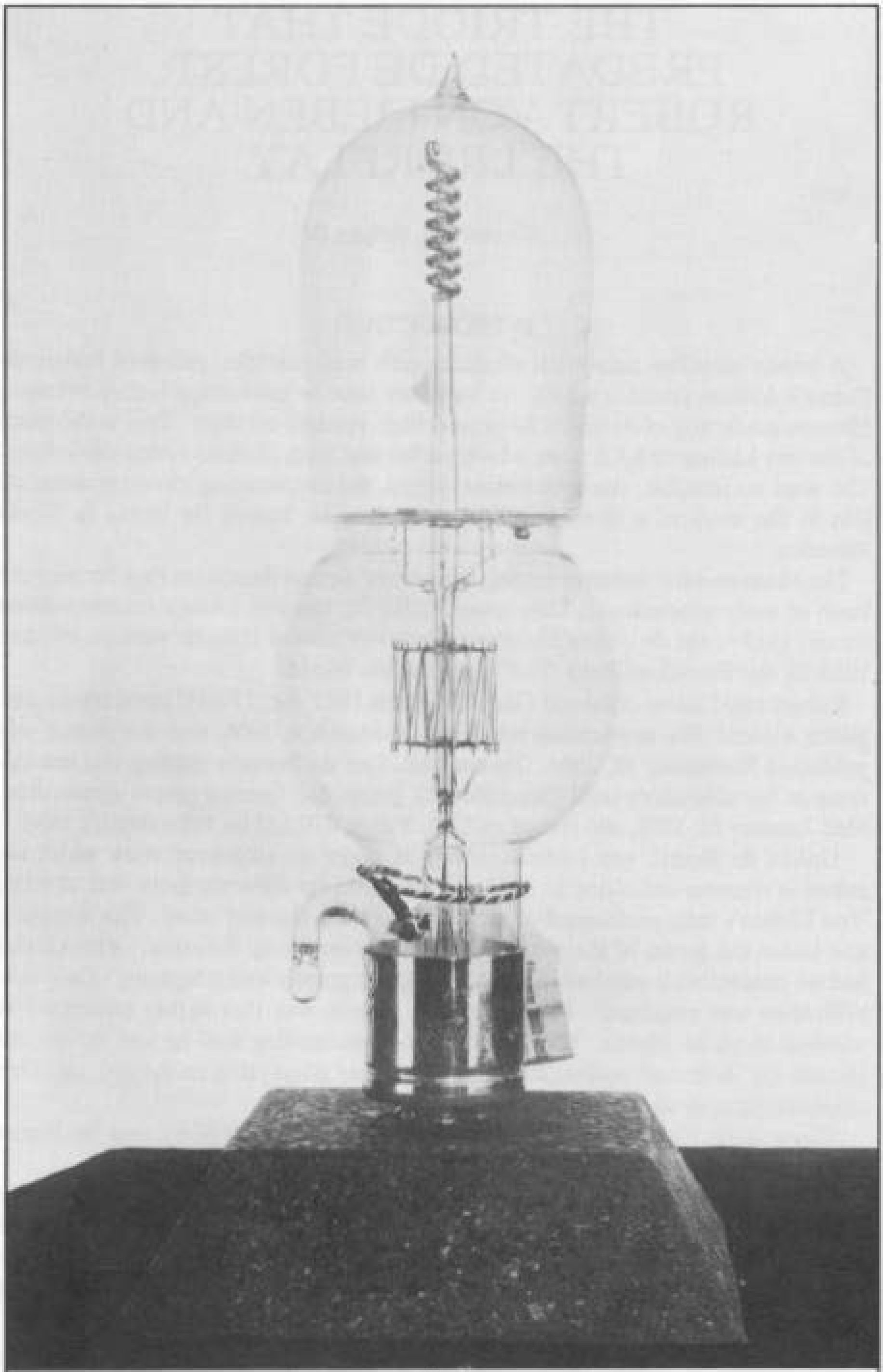


Fig. 1. LRS Relay, ca. 1913

Photo: Lauren Peckham

and long-time president of the Vienna Stock Exchange, at that time at the peak of the power and influence of the Austro-Hungarian Empire. As with Marconi, Robert's parents provided ample financial support, which later enabled him to maintain his own private laboratory, starting in his home.

He inherited his bent for things scientific from his uncle Adolph, a distinguished chemist at the University of Vienna. Another uncle, Richard, contributed to the financial and business acumen of the family.

Robert was not outstanding at school, for his independent spirit rebelled at the enforced discipline of the schoolroom. Nevertheless, he progressed through the Academic Gymnasium, and through the Reale Schule on the Hessegasse. Following the "middle school" he volunteered to serve in the elite Uhlan cavalry. Unfortunately, after but a few weeks he was thrown from his horse and impaled on a picket fence. This left him with a pierced lung, which did not heal properly. It gave him constant pain throughout his life, which ended when he was but 35 years old.

One might say that von Lieben was self-educated. He obtained practical shop experience through a year of manual work with Siemens in Nürnburg. He also audited courses in experimental physics at the University of Vienna.

In the spring of 1899 he went to Goettingen for a year of study under the brilliant Professor Walter Nernst. At that time Nernst was only 35 years old, yet had already achieved wide fame. The two men became fast friends, and their chemistries matched - as one might say today, they were able to "relate" to each other. Nernst had a strong effect upon von Lieben, and influenced his life and technical activities in later years.

At Goettingen, von Lieben devised an electrochemical phonograph which was demonstrated under the friendly eyes of his mentor. In 1903 he published a paper concerning polarization of X-rays. This was but eight years after Roentgen's discovery of these rays. In those days X-rays were generated in gaseous-discharge tubes. Thus, in his researches von Lieben obtained experience with the phenomena of discharges in gases and with cathode rays, all of which served him later on. These were the building blocks which he was destined to fit together into his successful telephone relay and radio amplifier.

Opening his own laboratory in his father's home furnished an outlet for von Lieben's energies. They were not needed in a daily race for survival, but had to be consumed in some useful manner, such as the science which he loved so much. "Germany made science a business, whereas other countries gave science the status of a hobby for rich men" [1]. Von Lieben combined the best of both definitions.

In appearance he had finely molded, almost girlish features, with dark Oriental eyes. One would have thought him to be a dreamer. He was inordinately shy, a trait emphasized when with strangers. But in his work, and with friends or in the laboratory, von Lieben became completely self-confident and intense, concentrating upon the subject at hand. He would immerse himself and work endlessly until the wee hours of the morning. He wished to see new ideas carried out promptly. He would adjourn with his associates for detailed postmortems of the work. These sessions were generally held in the nearby Hotel Bristol, which he favored for its fine food. At other times he would convene symposia with other prominent scientists, always over a table laden with good food.

Several illustrations indicate the breadth of von Lieben's technical interests and mechanical skills. While still a schoolboy he built an electrical generator and lighting system for his father's summer villa south of Vienna, at a time when such a system was a real rarity. He made improvements upon agricultural machines. Later he developed apparatus for photographing the human eye. He tackled the problem of an electromechanical coupling for the power train of a gasoline engine (which had first been put into automobiles only between 1897 and 1900). Later, during a visit to Paris he saw a Wright Brothers airplane. Fascinated, he purchased one of the machines, conceived improvements, modified the plane, and then presented it to the Austrian military (rather an inconceivable happening in 1990!).

Von Lieben appeared to be excited by the latest technical developments. As with so many other scientists, once they are bitten by an idea, the concept rules their lives until success is achieved [2]. "Lieben followed all progress in physics and chemistry with eagerness and perseverance, almost as an noble sport!" [3]. Then the idea of amplifying telephone signals captured his imagination. It did not leave him until his death.

Apparently he divided his time between Goettingen and his Vienna laboratory. By that time his mind was concentrating upon the telephone-amplifier problem and its solution.

TUBE DEVELOPMENT

About 1904, with financial backing from his father, von Lieben purchased a small manufacturer of telephone equipment, located in Olmutz, Moravia, now part of Czechoslovakia. A good deal of his time must have been expended in commuting the several hundred miles among the factory, the University and home. Railroads were the best available means of transportation in those days. He altered the name of the firm to Telephon und Telegraphenwerke Robert von Lieben - Olmutz-Wien. The business prospered and grew to employ several hundred men. It was during this period that former school teacher Dr. Eugen Reisz and engineer Sigmund Strauss joined the staff. Strauss came from Berliner Aktiengesellschaft (AG).

Von Lieben did not care for strictly regulated business life. He was happiest in his laboratory, where he could follow his own ideas freely. Consequently, he eventually sold the plant about 1909 to Berliner AG but retained rights to the partially developed relay. Strauss remained with him.

Before then, however, all the building blocks from various technologies were at hand. The telephone-equipment company brought the need for an amplifier forcibly to his mind. It was quite apparent that electromechanical devices could not follow weak telephone signals with the required accuracy, sensitivity and speed. In 1905 all the elements of the enigma suddenly fell into place. An amplifier, employing the control of cathode rays, was visioned, attempted, and found to work!

From the start of tube development, platinum ribbon coated with alkaline-earth oxides was employed as the electron emitter. This is truly startling, since Professor Wehnelt had published his work on the emitting properties of such oxides only as late as 1903-4 [4]. Von Lieben made use of these emitters almost

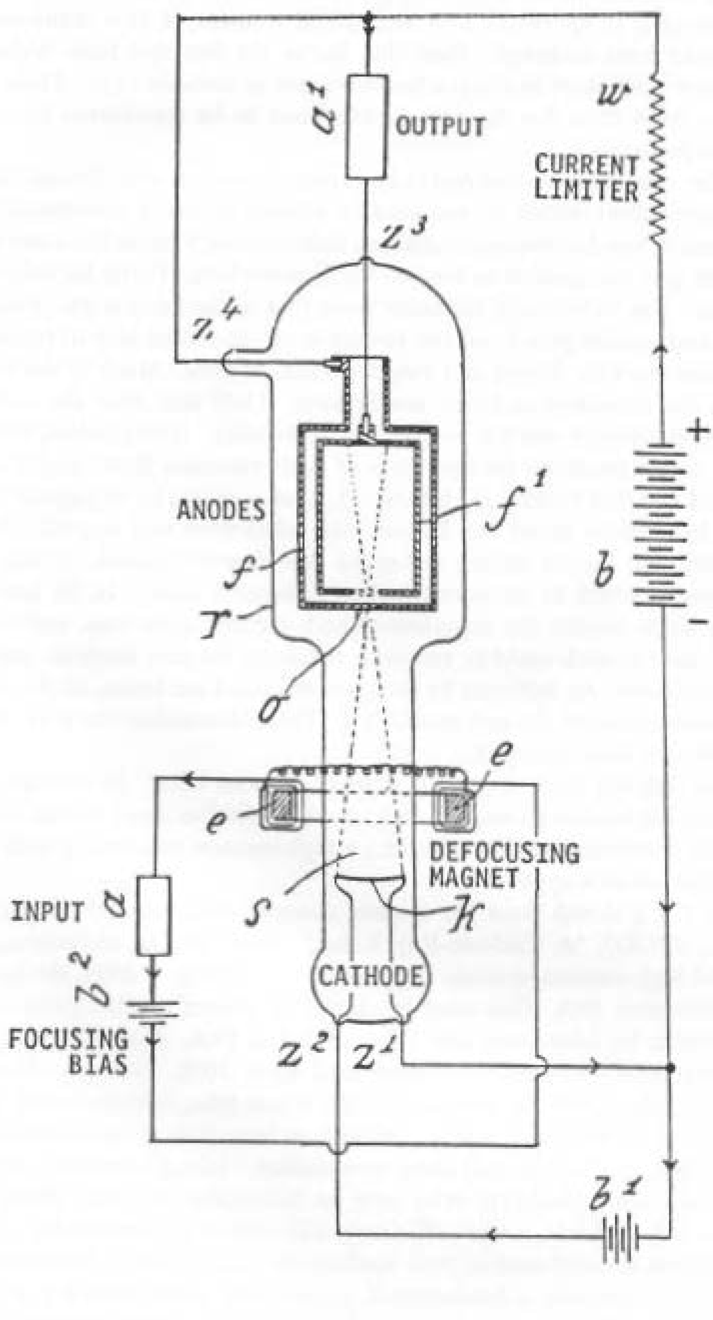


Fig. 2. First concept of von Lieben amplifier tube: a high-vacuum device with the beam defocused magnetically by the input signal. (Adapted from DRP Nr. 179, 507.)

at once (1905-6). Their advantage lay in the greatly reduced heater power required, as well as cathode rays being generated with but 200 volts on the anode. It is interesting to speculate how such rapid transfer of this brand-new technology could have occurred. One clue lies in the fact that both Wehnelt and Nernst were specialists in electrochemistry and in cathode rays. Their relation must have been close for the new development to be transferred to a favored student so promptly.

Once the original invention had been shown to work, it was obvious that much development effort would be required to convert it into a commercial reality. Consequently, von Lieben established an independent Vienna laboratory. Partly this was to give recognition to his two loyal co-workers. Partly his inherent shyness caused him to withhold his name from that of the laboratory. Further, the illnesses and related pain from the cavalry accident forced him to remain abed, absent from work for longer and longer periods of time. Much of the work thus fell upon the shoulders of Reisz and Strauss. Until that time the commercial success of the project was felt to have low probability. Nevertheless, von Lieben provided ample financing for operation of "Laboratorium Reisz und Strauss," in short, LRS. At first located at Hofzeile 21, it later moved to Vegagasse 21.

Reisz has written about von Lieben with admiration and respect. "I worked closely with von Lieben during the entire development period. It was unusual the manner in which he cooperated when difficulties arose. In the late evening hours he might modify the complicated high-vacuum apparatus, and would not rest until our research could be resumed, following the new methods and without further problems. At daybreak he then accompanied me home, all the while discussing every detail of the test results" [5]. These discussions were an important part of his own scientific work.

This was only the beginning of six years of arduous labor. In contrast, de Forest allowed his Audion to remain unchanged for the five years before Arnold assumed the conversion of that tube into a high-vacuum practicality with long life and widespread new applications.

Figure 2 is a sketch from the original concept, which resulted in issuance of DRP Nr. 179,807, "A Cathode-Ray Relay." This was an electromagnetically controlled high-vacuum version. Applied for on March 4, 1906, the patent was issued November 19th. One must recall that de Forest's rather gassy triode did not operate in his laboratory until the very end of 1906. His patent was filed for in January, 1907, but was not issued until early 1908. Thus, in Europe von Lieben is credited with the invention of the triode tube, having beaten de Forest to a patent office by almost a year, and with an issue date 15 months earlier.

In Europe, von Lieben had close competition. Max Dieckmann and Gustav Glage filed for a cathode-ray relay tube on November 10, 1906! While roughly similar to von Lieben's, it was sufficiently different to be patentable. The work of von Lieben is mentioned in their application. (As an aside, Dieckmann came very close to obtaining a fundamental patent some years later for a television imaging tube. He lost out to Philo T. Farnsworth by a close margin. Unfortunately second place does not pay off!)

The combined talents of the inventor and his patent attorney resulted in an exceptionally broad basic claim, which reads: "A cathode-ray relay for signals up to the *highest frequencies* [emphasis added] characterized by the well known fact that electron beams emitted from concave, oxide-coated cathodes are influenced by signals of increasing frequency so that the output frequencies are the same but with greater amplitude. * * * The use of this relay could be highly advantageous for many problems in telephony such as the transmission of speech over long distances by cable and by wireless. This relay could be useful in amplification of speech and music and for many problems associated with the transmission of photographs."

Use of the tube as an amplifier was not only envisioned but demonstrated several years before de Forest was able to do so. The German courts considered it to be a "pioneering invention." There were many patent cases, but the Leipzig court held in favor of von Lieben, and no appeal was ever taken from that decision.

It is interesting to consider why the concept of an inertialess electronic amplifier required such a long time before it was pursued by other investigators. George A. Campbell, in the Boston laboratories of AT&T, recognized the need as early as 1907. The ensuing depression of that year prevented active work on the concept. This same depression arrived in England in time to stop British tube development at the Post Office Research Station in 1908. Fortunately, the financial resources at the disposal of von Lieben did not curtail his efforts.

In 1910, Dr. Frank B. Jewett, then at engineering level with Western Electric's laboratories in New York City, gave recognition to the problem in his well known letter to Professor Robert A. Millikan, at the University of Chicago, which resulted in the recruiting of Harold D. Arnold and later of Hendrik J. van der Bijl. Dr. Jewett's letter stated in part [6]: "Such a device, in order to follow all of the minute modulations of the human voice, must obviously be practically inertialess, and I don't see that we are likely to get such an inertialess moving part except by the utilization somehow of electron streams which you have been working with in Physics for the past ten years."

It seems that von Lieben initially was interested as much in the pure-science aspects of his relay as in its commercialization. He wanted very much to publish scientific papers in the Physikalische Zeitschrift. It remained for Reisz and Strauss to urge him in the direction of a product which might give a financial return.

Strauss described the first demonstration of the relay in his paper as follows [3]: "In 1907 Lieben demonstrated the relay to his friends. This was in his private laboratory in the Opelsergasse #6 in Vienna. Through his relay a telephone conversation could be amplified with perfect clarity. Dr. Richard Leiser assisted with these experiments. His contributions were primarily concerned with obtaining a more uniform and longer-lived oxide coating. Also, engineer Eugen Reisz was an assistant. Reisz had abilities far above the average. He was rich in ideas, and was most clever with experiments." (Might not Dr. Leiser be termed the first tube engineer to battle low emission, hence deserving of the understanding sympathies of following generations of factory process engineers?)

Evolution of the practical tube design required several well-defined steps. Just to mention them by title will be sufficient to conjure visions of endless experiments, failures, argumentative discussions, and plodding advances in the minds of tube engineers from later years.

1. Change in the emitter design permitted reduction in current required from

20 to two amperes.

2. Improved pumping and maintenance of the vacuum which was so essential was achieved only after hard work over a long period of time.

3. An arc developed frequently near the anode, which would completely block tube operation. One attempt to eliminate the arc was to place a woven-wire mesh between cathode and anode. "It was similar to the screen used in Davy's safety lamp." (This should be considered a most significant statement, leading to the concept of the grid structure.) The mesh, plus a series current-limiting resistor in the anode circuit, completely eliminated the arcing.

4. It was observed that the input signal could be connected to the mesh. External magnetic coils were no longer necessary. Electrostatic control replaced electromagnetic! The dimensions of the mesh "grid" were found to control tube characteristics. By necking at the mid-point of the bulb, and extending the mesh completely across the narrows, it became possible to achieve even greater signal amplification. (In later patent applications statements were made which evidenced knowledge of de Forest's work with a triode grid.)

5. When attempts were made to seal the tube from the pumping stand, failures occurred at unpredictable times. Observation showed there were changes in the color of the ionized gas. Hundreds of tubes were made and discarded. The trouble ultimately was traced to low mercury pressure. Originally the tubes had been attached for long periods of time to Gaede mercury pumps. Backstreaming of the mercury vapor had fortuitously allowed vapors to enter the tube. After tip-off the gas "cleaned up" to a hard vacuum. This altered properties of the discharge in the tube. A droplet of mercury was purposely introduced into the bulb. Eureka - good tube life and uniform operation resulted - *success*!

Several additional patent filings were necessary due to the major alterations in design. Also, other investigators had been active in the field. The literature shows such names as Dieckmann, Glage, Otto von Bayer, W. J. Milham, C. Giesel, and Jonathan Zenneck. Thus, the von Lieben trio filed for a patent on September 4, 1910. This was published on July 11, 1911, as DRP Nr. 236,716. The more important patent was applied for on December 20, 1910. It was issued on July 12, 1912, as DRP Nr. 249,142, "Relay for Varying Currents."

During five years of development, the tube was so altered in structure as to be almost unrecognizable. Figure 3 shows the sketches from the later patent; it should be compared with the sketch shown in Figure 2 for the 1906 design. The photograph of Figure 1 corresponds with the tube design placed in production in 1912. As usually happens during manufacture of any product, there were further modifications. One of the forms taken by the tube during the WW I era or shortly thereafter is pictured in Figure 4. A design closer to conventional European triodes was employed, somewhat similar to the French TM receiving tube but significantly larger. It is unknown how this design compared in performance, or for what application it was intended.

By the end of 1910 the tube could be shown to operate as planned, with an acceptably long life and uniform characteristics. It could be cloned with assurance of success. During the early months of 1911 a great deal of thought must have been expended as to how to attract support from large organizations such as Siemens and Allgemeine Elektrizitäts Gesellschaft (AEG). Professor Nernst can be presumed to have been the pivotal contact for his former student and

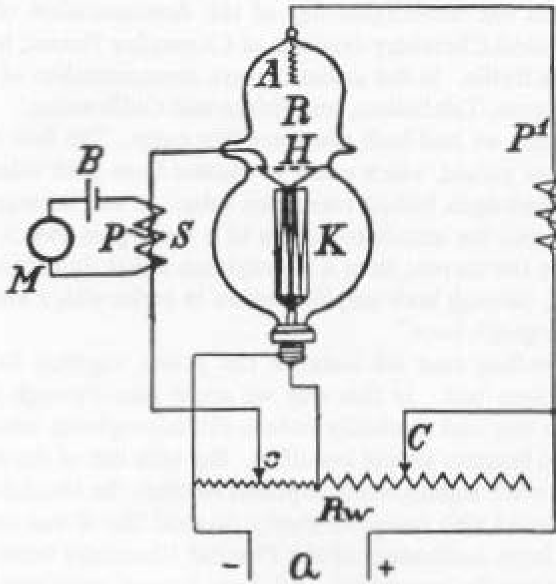


Fig. 3. Evolution to 1910: a gaseous device with the beam controlled electrostatically. (Adapted from DRP Nr. 249,142.)

Fig. 4. The final commercial form, with concentric elements. (Reproduced from Archiv Geschichte Mathematische Naturwissenschaften Technische 1930-31, 13.)

close personal friend. The climax of all the planning can best be described in the words of Strauss [3]:

"August 3, 1911, was the memorable day of the demonstration of the von Lieben tube at the Physical Chemistry Institute of Chancellor Nernst, located on the Dorothienstrasse in Berlin. In the audience were representatives of the great companies: AEG, Siemens, Telefunken, and Felten und Guilleaume."

"For this demonstration we had built two travelling cases. The first contained two Lieben tubes of that period, which could be viewed from both sides, in conjunction with an iron-hydrogen ballast resistance tube. It was arranged so the tubes could be placed into the circuit by means of a multi-pole switch. Thus it was possible to conduct the current from a microphone either directly to a headphone, or by switching, through both amplifier tubes in series with a loudspeaker having a wooden phonograph horn."

"In the second travelling case we installed the power supplies for the microphone and a resistance box. In this way we could pass through the many steps of the resistance box and gradually reduce the microphone current from normal volume so as to become almost inaudible. But with use of the multi-pole switch these inaudible voice signals were amplified through the two tubes. Then suddenly speech was heard with complete clarity, so loud that it was understood in the last row of the large auditorium of the Physical Chemistry Institute. The demonstration made a terrific impression. All those present were amazed - one might even say they were beside themselves!"

"At that time it was thought that the Lieben tube would be of use only as a voice amplifier. However, at once the large companies wanted a method which would permit simultaneous two-way telephonic communications. Obviously it was felt that many years would be needed to find such a solution. Fortunately by the Fall of 1911 we had arrived at a tentative solution which proved to be quite satisfactory."

The active participation of Robert von Lieben was becoming more and more curtailed due to his failing health. It is best to continue here with the narrative of the remaining 18 months of his life.

In 1927 Eugen Reisz wrote that during von Lieben's later years he was intrigued by the structure of the atom. "It is my memory distinctly, that his thoughts and ideas at that time were in exact agreement with the scientific experiments that have been made up to this time" [5].

Strauss wrote [3]: "In the summer of 1911 von Lieben married the beautiful actress Anny Schindler, the granddaughter of the famous poet Julius von der Taun. She had been appearing in the well known Burgtheater in Vienna. Thus, he then stood at the peak of his life, having found a beautiful wife, and having achieved success in his work. Then shadows began to fall across his path. A tumor formed in his chest, probably resulting from the riding accident sustained many years earlier. X-rays were used, and for a while gave him some relief from the increasing pain. Despite the best of care, Robert von Lieben died on February 20, 1913. He had lived long enough to see the acceptance of his work, but not the triumphs which were to follow."

Following his death eulogies were given by the outstanding playwright Hugo von Hofmannsthal, and by such outstanding scientists as Nernst and Einstein.

TUBE PRODUCTION AND APPLICATIONS

Demonstration of the LRS tube in August 1911 was the first time that a tube had ever been shown as an amplifier, capable of filling an auditorium with sound. The audience had been selected to include technical men as well as members of management who could make major decisions. Wilhelm von Siemens was present, and was thenceforth a strong advocate pushing formation of the Consortium that followed.

Siemens und Halske AG was prominent in telegraph and telephone systems in Germany and other parts of Europe. It had the technology needed for tube work through its dominance in the incandescent-lamp industry. Von Siemens immediately saw the solution for the needs of long-distance communication.

AEG and Telefunken were leaders in Germany in wireless communications and equipment manufacture. At that time they were engaged in a duel with British Marconi, attempting to break the near-monopoly held by Marconi on maritime wireless. Telefunken could see that early acquisition of the von Lieben patent could provide an advantage through protection in the manufacture of tubes, as well as in making and selling apparatus for wireless transmission and receiving, whether aboard ships or across the oceans. They recognized that further circuit development would be necessary.

Felten und Guilleaume apparently were desirous of augmenting the business of their equipment manufacturing division, predicting a wide new market for equipment containing electron tubes.

To this time there had never been seen or heard amplification based upon so much development work in depth by one small group, especially by a man with such excellent scientific backing and credentials. Germany felt fortunate that this occurred within her boundaries.

How did this compare with tube work in other countries at that time? In England, some of Fleming's diodes were being used as wireless detectors. But they were not favored by marine operators, in comparison with improved crystal detectors, due to noise and instability induced by gas content. There had been some tube work at the laboratories of Marconi, as well as the British Post Office. In 1908 Captain H. J. Round was working with poorly outgassed "soft valves." The depression of 1907-8 curtailed his project, and only low-level effort was expended until 1914.

A few "soft" tubes had been made in France but there seems to have been no real direction, goal, or centralization of effort. It remained for then-Colonel Ferrie to galvanize France into tube activity with the start of WW I in 1914.

In the United States, de Forest and his companies had bought about 700 Audions, made by McCandless, during the three years 1909-1911 (1909, 440; 1910, 214; 1911, 45) [7]. In that period all other customers had purchased but 228. Obviously this was but a low-level effort with the inventor. Practically all those tubes were used in detector sockets. To that time no one had found their amplifier or oscillator characteristic. De Forest had made *no* improvement over his 1906 design; he was deeply engaged in other wireless matters.

It would be another year (1912-13) before H. D. Arnold and his Western Electric associates would initiate their development work, which would convert the Audion into a "hard vacuum" triode, thus opening up entirely new vistas for tubes and their applications. Tube work in any other country, if any, was confined to academic research.

The Consortium formed to exploit the von Lieben patents was of a restricted nature among AEG-Telefunken, Siemens und Halske, and Felten und Guilleaume Carleswerke AG. It was signed February 19, 1912. Exclusive rights to the von Lieben group patents were assumed by the four companies [8]. The agreement was limited to sharing costs and benefits among the participants on a 45%-45%-10% basis respectively. Basic research would be performed at a laboratory established in the AEG Oberspreewerke. Development and manufacture of tubes and equipment were to be performed by the member best suited for that work.

Much work was needed to adapt the radical new active component to practical and useful circuits. Fortunately Reisz, Alexander Meissner, and others soon devised the needed circuits, as shown by ability to use the amplifier in two-way telephone repeaters. Development of radio equipment for military use became very important, as evidenced by the large production volumes during the war by the TeKaDe equipment division.

In what manner did the von Lieben group participate in the Consortium, and how were present and future patent rights assigned to the Consortium or its members? What financial rewards were arranged or paid with the von Lieben group? None of the references available make any mention of these problems or their resolution. Written requests to the companies have drawn no response. The passage of 80 years of time, the intervention of two destructive wars and a great depression, and corporate reorganizations have militated against ever finding answers.

It is known that Reisz moved to Berlin and headed the laboratory at the Oberspreewerke. Strauss remained in the Vienna laboratory to be in close touch with von Lieben, who was confined to his bed for longer and longer periods.

Felten und Guilleaume promptly changed the name of the Carleswerke division to reflect its planned new products better. The name became Suddeutsche Telephon Apparate, Kabel, und Drahtwerke AG (South German Telephone Apparatus, Cable, and Wire Works Co.). The patented trademark was $_{k}{}^{T}{}_{d}$, later known as TeKaDe. Manufacture of equipment for telephone central offices was a major product, along with wire and cable for communications and power distribution. Siemens was the major customer.

Volume production of the tube was assigned to Siemens-Osram Plant A on Sickingerstrasse, Berlin, with Dr. Pirani in charge of the project. (In 1915, Pirani invented the vacuum gauge which bears his name and which was used universally for many years.)

It was already known that a constant mercury-vapor pressure was essential for stable tube operation. Its control was attempted in two ways. Some tubes have a vertical millimeter-type scale etched into the bulb just above the plane of the grid mesh. This was to indicate the optimum height of the dark space which was present beneath the blue ionized gas. The second was enclosure of the tube in a chimney to provide a cooling air current by stack action. Here, too, a vertical scale could sometimes be found as an indicator of the optimum operating condition.

Efforts to control the tube and improve it were not lacking. Bulb height was reduced to about seven inches. Various mesh sizes and perforated metal sheets were used at the grid plane to provide different amplification and current-controlling conditions.

Data for an early production LRS tube are of interest [5]:

Overall length	8.7 in. (22 cm)
Overall diameter	4.15 in. (10.5 cm)
Amplification	3.5-4.0
Life expectancy	400 hours.

The lifetime was considered quite good for such an early stage of development. Later tubes had higher gain and longer life.

Table I lists the chronology of many events which transpired in rapid succession after 1911. Study of this table tells a great deal about the importance attached to the LRS tube in Germany. Note that the public demonstration of the tube was carefully scheduled after patent protection had been assured to the von Lieben group. Further, the Consortium became a legal entity only six months after the demonstration. This is a remarkably short time when one considers the number of groups involved, their spatial separation, and the time usually required by legal departments to draw up the necessary contractual terms. This certainly indicates the importance attached to the project. Note further that the technical staff had the OSW laboratory in operation only two weeks after the contracts were signed.

In 1912 an international conference was held in London concerning regulation of wireless telegraphy. Its importance was underlined by the recent sinking of the Titanic and loss of life, which would have been less had there been greater use of wireless on ships. There needed to be coordination among the communications companies. At that time Marconi held almost a monopoly and there was a great deal of conflict between the companies of other countries.

Telefunken was able to display new equipment developed through the rapid circuit work of Meissner and others, which included the LRS tube. The tube was even used as a table decoration, proudly displaying the red of the filament area, and the blue of the ionized mercury. This greatly strengthened the hand of the Germans. Thus, just a few months later Marconi and Telefunken signed an agreement concerning tube and equipment development. Captain Round of Marconi was to concentrate upon development of receiving valves. Telefunken would concentrate on evolving transmitting valves. (This agreement did not last long, due to the outbreak of WW I.)

Tube processing was all done on stationary or "trolley" exhaust positions. Rotary or semiautomatic pumping stands were still years away. Tubes with greater power-handling capability were needed, as well as smaller ones for portable military apparatus. The glass bulbs, stem-making, and bulb sealing required the services of skilled glass workers. Metal parts, even the anode, used wire. The grid was usually a woven-wire mesh, the production of which was a specialty of German industry.

AEG built the first telephone repeaters using LRS tubes and submitted them to the Reichspost for approval. This was obtained at the end of 1912. Each fresh application of the tube required circuit development and new equipment designs to accommodate the new component. Innovative uses needed "selling" to potential customers - not difficult at that time, since the Consortium members

TABLE I
CHRONOLOGY OF THE VON LIEBEN TUBE

<u>1910</u>	
Sept. 4	Patent application filed.
Dec. 20	Patent application filed.
<u>1911</u>	
July 11	Patent DRP Nr. 236,716 published in response to Sept. 4 filing.
Aug. 3	LRS tube demonstrated in Berlin at Nernst's Institute.
<u>1912</u>	
Feb. 19	Consortium agreement signed by the four companies.
Mar. 1	AEG-OSW Lieben-tube development laboratory in operation.
July 9	F & G Carleswerke reorganized and renamed.
July 12	Patent DRP Nr. 249,142 published in response to Dec. 20, 1910, filing.
Aug. 2	Name of F & G's new division registered: TeKaDe.
Oct.	LRS tube and transmitter displayed at London conference.
Oct. 15	Telefunken files for a patent on base and socket for LRS tube (DRP Nr. 264,554, Sept. 26, 1913).
<u>1913</u>	
Early	Dr. Pirani starts commercial production of LRS tube at Osram Werke A.
Feb. 20	Robert von Lieben died.
Feb.-Apr.	Reisz and Strauss meeting with AT&T to sell LRS license.
<u>1914</u>	
	F & G purchases Wolfram-Lampen AG, Augsburg.
Aug. 1-3	WW I begins.
<u>1915</u>	
	Production of LRS tube by Consortium in Berlin.
<u>1916</u>	
	TeKaDe required to assume production.
<u>1917</u>	
Mar. 21	Fire destroys tube and lamp plant.
<u>1918</u>	
Summer	TeKaDe resumes production of LRS tube but for only a few years.

and the military were the chief users. With the staff of excellent circuit engineers assigned to the project, there was rapid progress.

Soon two danger signals appeared. First was an investigation for Siemens by the tube laboratory of Akkumulatorenfabrik AG, a Berlin manufacturer of storage batteries and mercury rectifiers. Their investigations of mercury vapor showed that the tube would be inherently noisy and that maintenance of the optimum vapor pressure would be almost impossible, since environmental temperature would need accurate control. Second, work at General Electric and Western Electric in the U. S. with an improved vacuum, using the recently introduced Gaede pump, showed great promise. Consequently, AEG concentrated on the new high-vacuum approach for tubes, while Siemens continued development of the LRS tube for a while longer.

On April 10, 1913, Dr. Meissner of Telefunken applied for a patent using the LRS tube in a transmitter. On June 21 he was able to conduct a radiophone conversation between Berlin and Nauen, a distance of about 25 miles (40 km). It demonstrated the use of the tube as an oscillator and modulator. For those days, with the low power of the LRS tube, that was a remarkable feat.

Dr. Hans Rukop of AEG was placed in charge of a laboratory on the Tempelhofer Ufer, Berlin, to evaluate performance of high-vacuum triodes, following the lead of Arnold at Western Electric. All these efforts benefitted from availability of the improved Gaede pump. Rukop operated his first successful high-vacuum triode at the beginning of August 1914, just as WW I was declared. Thus, the LRS tube had two years of growth without a rival. The next two years saw development of the "hard" triode to the point where Telefunken and Siemens were no longer willing to produce the LRS tube, having adopted the policy of using high-vacuum devices. Thus, they forced Felten und Guilleaume to assume production of the LRS tubes which might be needed.

Equipment using the LRS tube was not confined to telephone repeaters. Telefunken and TeKaDe assembled large amounts of other apparatus during the war. Shipboard wireless used LRS tubes in high-frequency amplifiers and heterodyne oscillators. Such equipment was found on the SS Vaterland when she was interned in New York in August 1914. In well under two years, this was truly a rapid development into commercial equipment.

It was fortunate that Felten und Guilleaume had acquired a lamp manufacturer in 1914, Wolfram Lampen AG of Augsburg. Thus facilities and technology were available when assumption of LRS production became necessary in 1916. Unfortunately, less than a year later the plant was completely destroyed by fire. Production could not be resumed until just as the war ended in 1918. It is probable that all production of the LRS tube had ceased by 1920, since high-vacuum tubes were rapidly replacing the mercury-vapor type, and were providing higher reliability, longer life, and lower cost.

Just before the major battles at the Tannenberg Marshes, the sensitive telephone equipment just recently available made it possible for General von Hindenberg's staff to eavesdrop on the Russian lines and to learn their battle plans, aiding the German victory there. Use of the LRS tubes in telephone repeaters extended voice communications from Berlin to Constantinople [Istanbul], a real necessity during the war. German Army headquarters in Luxembourg could maintain voice contact directly with both the Eastern and the Western Front.

Strauss [3] recounts that during his military service he was stationed in a remote and very hot little town in Yugoslavia, where there was one of the tube repeaters. It was not working well. Strauss was called upon to work his magic. By enclosing the tube in one of the chimney devices the temperature was reduced, and performance was again reliable.

CONTACTS WITH AT&T

Early in 1913, just a year after formation of the Consortium, Reisz and Strauss arrived in New York for meetings with AT&T. Upon arrival they received a cable telling of von Lieben's death. Presumably the mission was on behalf of, or with the knowledge of, the members of the Consortium. This trip might seem unusual in view of the close relations between Siemens and General Electric, which was also developing electron tubes. Further, the Reichspost and all the other major-country telephone companies were in close contact and presumably had patent exchanges.

Western Electric's laboratory first heard of the LRS tube through an article published in August 1912, and received by them on September 10th. Immediately the manager of the Bell Telephone Manufacturing Co. factory in Antwerp was requested to obtain and forward copies of the three pertinent patents. Thus, it is certain that Arnold was aware of the LRS tube prior to the visits.

To show just how close was the race for development and control of tubes and repeaters, consider these facts and dates:

1. Fritz Lowenstein made the unsuccessful demonstration of his "black box" to AT&T in January 1912. It was later disclosed that the box contained a de Forest Audion.

2. De Forest made his demonstration to Western Electric and AT&T on October 30-31, 1912. AT&T finally purchased certain de Forest patent rights about April 1913.

3. Arnold had been working on a mercury telephone relay. He had perfected it to the point that it was installed as a stand-by element in the event the hard-triode amplifier proved unsatisfactory during the New York-Baltimore trials in October 1913, and the preparations for transcontinental service in July 1914. This relay must have been essentially complete by February 1913, since Arnold by that time was in full pursuit of the high-vacuum triode version.

Reisz and Strauss could have known of none of these events. Consequently, they felt their reception was cavalier, and were highly disappointed that they were unable to sell the complete LRS patent rights and technology. Their sample tubes were kept by Western for six weeks of testing, without the co-developers being allowed to be present. They had felt the grid claims of the patent were outstanding, not being aware that AT&T was even then negotiating with de Forest.

There is evidence that there were legal conflicts between the de Forest and the LRS grid claims in later years. In Germany at least, they were settled in favor of von Lieben.

Arnold's mercury relay was based upon developments by Peter Cooper Hewitt with discharge tubes [9]. It is ironic that Cooper Hewitt was also thoroughly familiar with de Forest and his Audion. Their laboratories were in towers only a few blocks apart in New York City. De Forest's wireless signals were received by Cooper Hewitt, and the two men discussed the results by phone and in person. Even more ironic, the distance from de Forest's several laboratory sites to the Western Electric laboratory was less than two miles.

SUMMARY

The von Lieben tube had a production life of only eight years. Nevertheless, it merited a prominent position in the founding of the electron-tube industry. The tube derived from the inspiration of an unusual and brilliant scientist. Not content with proving his initial idea, he spent four years developing it into a practical entity. One may well say the production of the tube in 1912 by the outstanding electrical companies of scientific Germany provided the very start of tube production which founded a fantastic worldwide industry.

ACKNOWLEDGEMENTS

To Gerald F. J. Tyne, who almost singlehandedly brought an appreciation of von Lieben's work to this country. His earlier researches and then presentation in his Saga of the Vacuum Tube have spurred our interest in this remarkable invention, and a desire to see its story extended.

To Franz Mock of Vienna, Austria, and Dr. During of Aachen, West Germany, for locating references.

To Jacob Verwer, formerly of the Netherlands, and Mrs. Irmgard Kannengieser for aid in translations.

REFERENCES

(German titles translated)

1. MacLaurin, Sources of Invention and Innovation in the Radio Industry (New York, MacMillan, 1949), p. 5.

2. Ibid., p. 62.

3. S. Strauss, "Aus der Geschichte der Lieben Röhre" ("On the History of the Lieben Tube"), Der Radioamateur (Vienna: ERB Verlag, Mar. 1938).

4. T. H. Briggs, "Arthur Wehnelt and His Wonderful Cathode," The Old Timer's Bulletin, Vol. 23 No. 3 (December 1982), pp. 19-20.

5. E. Reisz, "The Life of Robert von Lieben," Natur Technische Zeitschrift, Vol. 31, No. 9 (1928), pp. 239-241.

6. M. D. Fagen, ed., A History of Engineering and Science in the Bell System - The Early Years (1875-1925) (Murray Hill, NJ: Bell Telephone Laboratories, Inc., 1975), p. 258.

7. G. F. J. Tyne, Saga of the Vacuum Tube (Indianapolis: H. W. Sams & Co., 1977), pp. 108-109.

8. 25 Years of Telefunken, 1903-1928 (Berlin: Telefunken AG, 1928).

9. As [6] above, pp. 256-258.

RELATED READING

"50 Year Jubilee of Telefunken," Telefunken Zeitung, Vol. 100, May, 1953.

"50 Years of Development & Manufacture of Electron Tubes by the House of Siemens," Siemens Zeitschrift, Vol. 36 (Feb. 1962).

"50 Years of TeKaDe" (Nürnburg: TeKaDe, 1962).

Herrmann and Wagner, The Oxide-Coated Cathode (Leipzig: J. Barth, 1944).

Reithoffer, "Robert von Lieben," Die Radiotechnik, Vol. 8 (May 1927), pp. 57-60.

H. Rukop, "Die Telefunkenröhren und ihre Geschichte" ("Telefunken Tubes and Their History"), Telefunken Fest., 1928, pp. 114-154.

Karl Przibram, "Robert von Lieben," Neue Österreichische Biographie 1815-1918 (Vienna: Erste Abt Bd 6, 1929), pp. 175-179.

K. Skowronnek, "Die Entwicklung der Elektronenverstärker-Röhre (Lieben-Röhre)," ["The Development of the Electron Amplifier Tube (Lieben Tube)]," Archiv Geschichte Mathematische Naturwissenschaffen Technische 1930-1931, 13: 225-276.

Zur Liebenfeier "RAVAG," Radio Wien, No. 30, Apr.-May 1927.

G. Carneal, A Conqueror of Space: An Authorized Biography of the Life and Work of Lee de Forest (New York: Liveright, 1930).

Thomas H. Briggs IV

Thomas H. Briggs IV was born in Charleston, Illinois in 1906. He received a BS degree in physics from Wesleyan University and an MS from California Institute of Technology. He held a variety of positions in the expanding tube industry, as Development Engineer for Westinghouse Lamp Co. and Chief Manufacturing Engineer for Raytheon and then the Special Tube division of RCA. He later became Manager of Manufacturing - Engineering and then Program Manager for the Burroughs Corporation, and finally president of his own consulting firm, Briggs Associates, Inc. He served with a number of industry standards groups, among them acting as chairman of the Joint Military-Industry Committee on Microwave Tubes and chairman of the ASTM Committee on Electron Devices. Mr. Briggs passed away in 1983.

SPIES USE RADIO

THE RADIO INTELLIGENCE DIVISION IN WW II

George E. Sterling, W1AE
Portland, Maine

[This article is a consolidation of Sterling's history as serialized in the Old Old Timers Club "Spark Gap Times," August 1963 to August 1964.]

INTRODUCTION

The story which I am about to narrate encompasses the operations of the Radio Intelligence Division, Engineering Department, of the Federal Communications Commission immediately before and during World War II.

During the 1940-41 period of neutrality, while war was being waged in Europe, new responsibilities were imposed on the Commission. They fell particularly on the Field Division, which was responsible to enforce radio rules and regulations and international treaties as to the technical operation of radio stations.

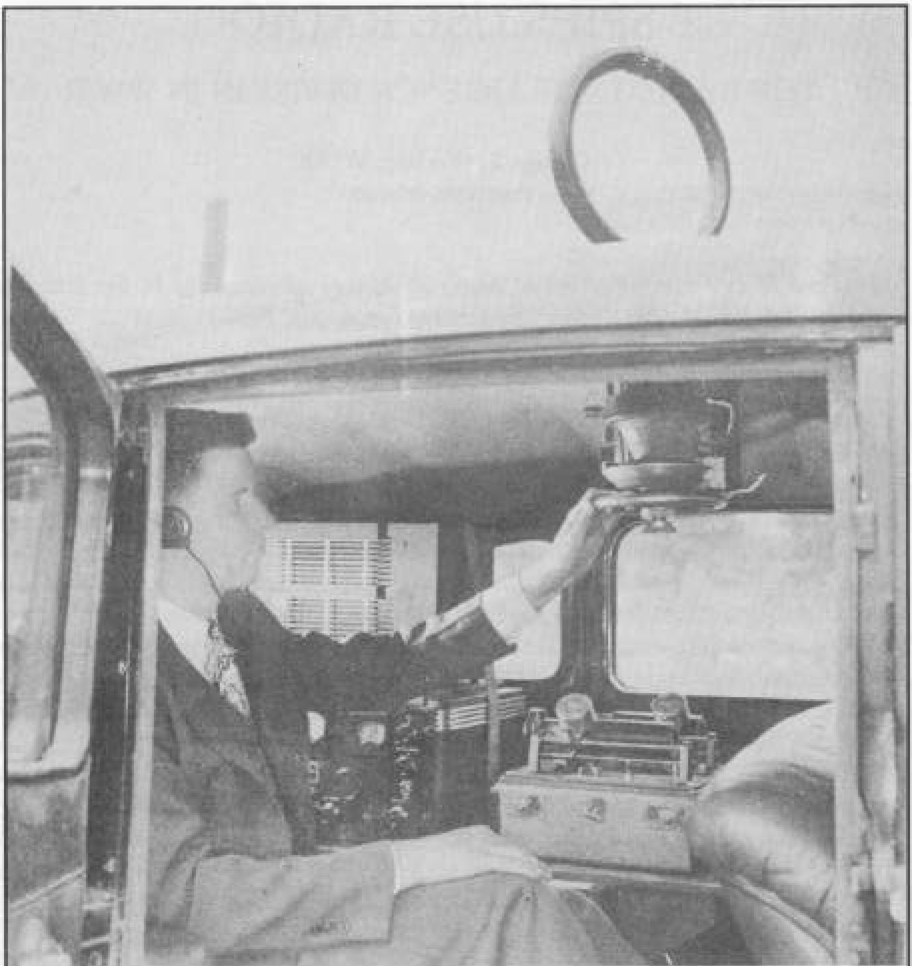
Reports of fifth-column activities by enemy agents in Europe using radio transmitters gave cause for alarm should they spread to our hemisphere. Moreover, it was essential to keep the channels of communication free of interference.

At this time the Field Division had only seven monitoring stations, whose operations were confined mainly to frequency measurement and analysis of the emissions of stations. None of these stations had high-frequency Adcock direction finders, recorders, or other essential equipment. Three were poorly located, with no room for expansion. One was on a Navy munitions site where there was a limit on the numbers and heights of antennas. Another was on the grounds of a West Coast fort where artillery practice interfered with monitoring, and a third was at a Navy radio training-school location where interference was becoming intolerable. The field offices were not equipped with mobile direction finders to locate an illegal station or a source of interference quickly.

So, in the face of the alarming use of radio by German spies in Europe and of the special problems at home, the FCC acted to put this country in a state of radio preparedness. A plan was drawn up to modernize and increase the number of monitoring stations and to provide mobile units. There was to be at least one station in each state to do local investigations, pinpointing illegal stations and sources of interference.

The plan was approved by the Bureau of the Budget and President Roosevelt allocated $1,600,000 from his emergency fund. Congress later supplemented the grant. Before the war came to America, the monitoring system, identified first as National Defense Operations, then the Radio Intelligence Division (RID), was mobilized with equipment and trained men. RID was neither too little nor too late. There was no Pearl Harbor in radio surveillance. When war came upon us, RID was given a share of duties far beyond what it ever thought it would be called on to perform.

From its inception until the end of the war, RID intercepted hundreds of



RID prowl car. Loop does not show while in motion, only when a bearing is being taken. Note SX-28 receiver and Dictaphone recorder. Other receivers in car cover 75 kHz to 300 MHz.

All photos: George E. Sterling/OOTC

coded messages sent by German espionage agents all over the world and supplied government cryptographic laboratories with these messages at their specific request.

In performing its "patrol of the ether," RID located enemy agents with their transmitters in the Western Hemisphere, Africa, Europe, and Asia. It sent radio-intelligence engineers to Latin American countries in accordance with a hemisphere defense plan to help clean out the German spies there. It also trained representatives of those countries in radio-intelligence techniques at its specialized school at Laurel, Maryland.

With funds furnished by the military, RID performed a host of military-intelligence duties on the mainland and in Hawaii and Alaska. It established radio-intelligence centers in San Francisco and Honolulu which were manned by Army, Navy, and RID men around the clock.

RID was the first to detect many intriguing clandestine operations. It monitored neutral and enemy commercial radio circuits, recording the transmissions on tape and then producing typewritten copies for the Board of Economic Warfare and the FBI. By examining this traffic, it was learned what the enemy's shortages were so that we could send buying agents into neutral countries to outbid them on merchandise for their war effort. This also provided a means of determining what big-name individuals were traveling between enemy countries as well as to neutral ones.

One of the most surprising and gratifying services performed by RID was the rescue of military planes lost in the blackout or having cockpit trouble. It located distressed aircraft by providing fixes from their radio signals and got them back on a normal course. It trained Army Air Force personnel in this service and aided them in setting up their own networks.

To meet requirements of the coastal defense commands, RID extended its surveillance to the coastal regions by mobile patrol, looking for evidence of surreptitious communication with submarines by Nazi agents, particularly those that might be using beamed VHF frequencies that would not be heard at fixed sites.

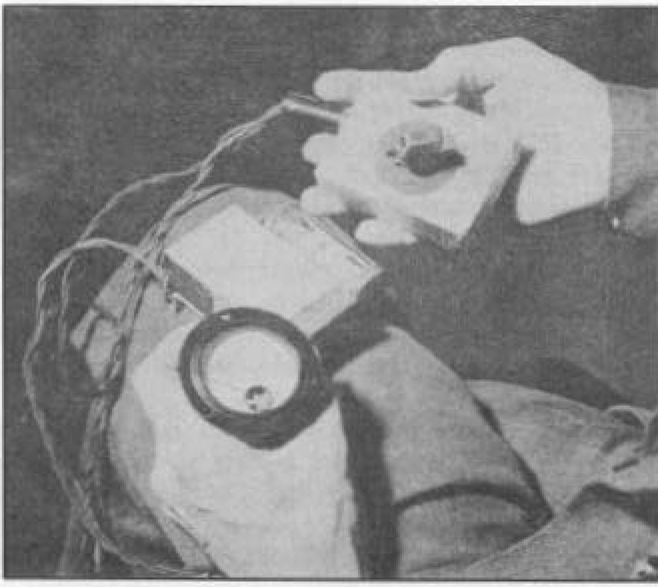
A separate branch of RID, identified as NDA, monitored and recorded worldwide high-frequency voice broadcasts of press and enemy propaganda for the Foreign Broadcast Intelligence Service, another FCC wartime division which published texts, translations, and analysis of the recorded material for a variety of government consumers.

RID trained Office of Strategic Services (OSS) men in radio-intelligence techniques and built equipment for their use. Its personnel also patrolled the outside of the Oak Ridge, Tennessee, site of the Manhattan Project, but without knowing what atomic developments were being made inside.

Since the Army and Navy transferred funds to RID to assist their radio-intelligence efforts, it was necessary for the Division's facilities and procedures to be inspected by a security board of military officers. Fortunately, my experience in radio intelligence in World War I led me to instill the proper military security in the organization and operation of RID. After going over RID with a fine-tooth comb, they reported as follows: Cryptographic Security: Excellent; Physical (Cryptographic Systems): Excellent; Documentary and Information Security: Excellent; Qualifications of Personnel: Excellent.

Wartime demands of the Division required development of new and improved tools to accomplish these projects. Fortunately RID had on its rolls many excellent radio engineers who lent their skill and know-how. As Chief of RID, I appointed Charles Ellert, W3LO, as Technical Advisor. Under his direction great strides were made in improving the Adcock DF resulting in far greater accuracy than had been obtained from purchased equipment. In fact, one of our English counterparts reported that the accuracy of RID bearings and fixes was far better than obtained from military sources.

Since we had neither men nor money to provide multichannel surveillance over suspects who might be engaged in clandestine operations, it became necessary to develop a radio receiver which would respond to any signal within the communication spectrum, yet was insensitive except to the strongest signal. Out of this requirement an aperiodic (untuned) receiver was developed by RID engineers James Veatch and William Fellows. This receiver was used to advantage in mo-



The RID "snifter" used to case hotels and apartment houses. Antenna down the user's pants leg; equipment concealed under the coat with the meter wired down the sleeve. The transmitter room was located by hot-and-cold procedure.

bile units and in providing surveillance at fixed locations such as Japanese internment camps. It was subsequently adopted by the Navy and OSS.

RID employed the panoramic receiver developed by a Dr. Wallis in his New York City laboratory for the first time in counterespionage operations.

Under Ellert's supervision, the "Snifter" was created. This was a simple receiving device contained in a small pack and worn around the waist under one's coat. An antenna could be trailed down the inside of the operator's pants leg. To register the signal either a hearing-aid earphone or a hand-held meter was utilized. The Snifter was used when casing the corridor of a hotel or apartment house or on the roof of a building containing many antennas to pinpoint the location of a transmitter. The device was named by a distinguished British astronomer, Col. F. J. M. Stratton, who provided liaison between RID and its British counterpart, the Radio Security Service of the Royal Signals.

Also on the RID list was employment of the selectable-sideband adapter developed by James McLaughlin and fitted to the Hallicrafters SX-28 receiver. The selectable-sideband feature was used to advantage to reduce effects of jamming while recording foreign broadcasts. The SX-28, among many other types, was the workhorse of RID.

The nucleus of the staff of RID came from the ranks of the Field Division, radio men like Ralph Renton and Forrest Redfern who had gained considerable experience in locating illegal radio stations. Examples were those of rum-runners during the Prohibition days, racetrack touts trying to beat the bookies, and pranksters. Monitoring officers and radio operators were recruited from industry and the amateur ranks. In fact about 80% of the men in RID were or had been amateurs. They made a tremendous contribution to the defense of their country as did the other men and women in the "Silent Service of RID."

Many of the women of RID at the monitoring stations became very proficient in producing typewritten copy from miles of Boehme tape recordings made from the radio circuits of the enemy and neutral countries. This required a special skill since the recordings were made with a type of stylus making both horizontal and vertical characters.

RID received excellent cooperation from the manufacturers of receivers and other equipment. Special mention is made of help received from the Hallicrafters organization, which went all-out to supply us with receivers; the Hudson Motor Company, which modified a production run of their passenger cars at no additional cost so that they could be used for undercover work with DF loops without attracting attention; and the Dictaphone Company for providing recorders.

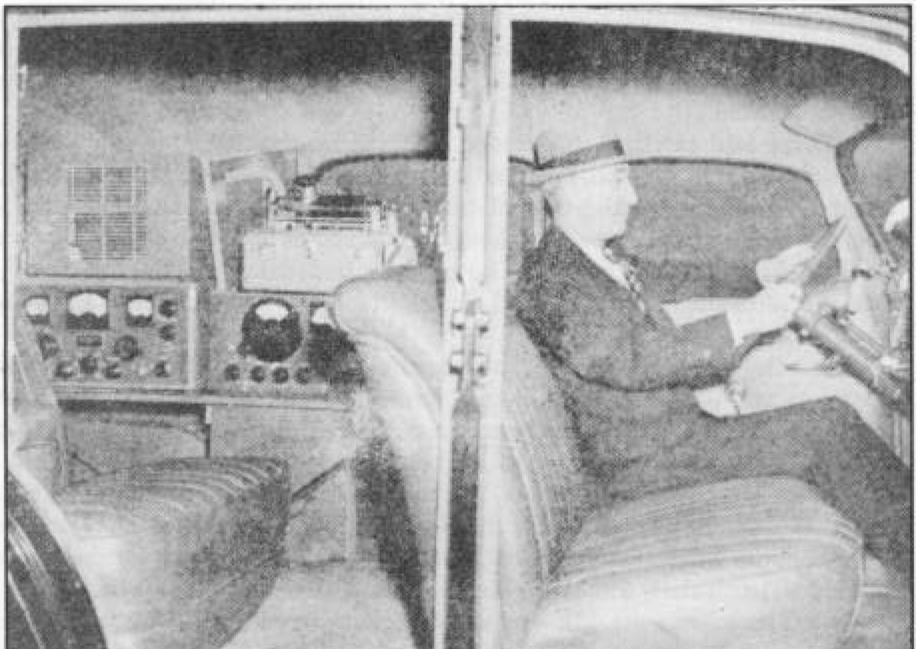
When the war was underway, most manufacturers were loaded with defense contracts and not interested in small orders. Consequently RID persuaded Manuel Kann, W3ZK, of Baltimore to manufacture aperiodic receivers and Adcock DF parts in the basement of his home at night, aided by off-duty technicians from local broadcast stations. Before Kann knew it he was up to his neck in the manufacturing business for the Navy and OSS as well as RID. I imagine his neighbors wondered what went on in his house with lights burning in the basement, particularly with men going in and out all hours of the night.

As will be seen in the following chapters, the personnel of a lively secondary station or a busy primary one supplied only a portion of what appeared as an intricate puzzle. From the fragmentary parts, the final picture was assembled at RID headquarters in Washington. The first information that led to the development of a substantial case often came from a single operator on duty hundreds of miles from the transmitter of the German espionage system. The person making the intercept never knew at the time he had furnished the first clue to a new station in our hemisphere or in Africa. The RID men working in Latin America at times had direct contact with spies but throughout the entire period of operation the information gained by each individual was held in the strictest secrecy and was made known only to those in authority.

I recall giving a talk before the Baltimore section of the Institute of Radio Engineers right after the war, in which I disclosed several RID cases. Some of the engineers of the Laurel station were in attendance. They came to me at the conclusion of the talk and told me that they never realized that their site had participated in the cases until I revealed it.

During inspections of stations during the war, I was frequently asked if, after the war, a history of the organization and its accomplishments would be furnished. A promise was made to do so. It is my hope that the disclosures which follow will honor the loyal men and women who served so devotedly in the organization.

One thing which highlighted RID accomplishments was a movie depicting its responsibilities and mode of operation. In 1944 Metro-Goldwyn-Mayer produced a two-reeler called "Patrolling the Ether." A 20-minute fictional version of RID's more dramatic adventures, this was incidentally the first motion picture ever to be shown on television, on the NBC affiliate in New York City. James L. Fly, chairman of the FCC, came up from Washington to appear in a televised preface to the movie along with various industry executives and myself. Mr. Fly, in introducing the movie, paid tribute to the Division's prowess.



RID mobile intercept/DF unit with monitoring officer Lewis Meriweather.

Who do you suppose gave technical assistance during the filming of this historical movie? None other than Tom Stevens, W6KAA, RID monitoring officer in charge of the Los Angeles area. I was privileged to visit the set with Tom as the show was put together.

THE FIFTH COLUMN THREATENS

It was a foregone conclusion that enemy spies would use radio in the war that was creeping upon us. As the Nazis swept over Europe, agencies of the U. S. government received reports of their feats of espionage. German agents carrying innocent-looking suitcases containing complete shortwave equipment plopped down in England by parachute. They landed in Africa from submarines. Dozens of stories of the activities of a German fifth column came out of France. One stated that agents dressed as French officers and using pocket shortwave sets sent misleading information to the French high command. Other reports told of clandestine radio activities in this hemisphere.

During this period of neutrality on the part of our government, thousands of amateurs in the U. S. owned and operated shortwave transmitters, while thousands more transmitters could be purchased on the open market. Any competent radio man could change a broadcast receiver to a transmitter. It was comparatively easy for an enemy agent to hide his transmissions in the activities of 60,000 amateur stations. As we shall see later, one German agent was sent over to this country with instructions to do just this. Diathermy machines were a natural for use as transmitters.

The FCC had no way of determining whether foreign ships within our neutrality zone were maintaining radio silence, as required, since the monitoring stations had no direction finders. These factors made the problem of sealing this country against Axis spy transmissions exceedingly difficult.

In the meantime, a few days before the Germans took Paris, amateurs were prohibited from communicating with foreign stations. Subsequently, the Board of War Communications, an agency established with representation from interested agencies of government and industry to control U. S. communications, acted to close all point-to-point radiotelegraph circuits to foreign countries. There was always a possibility of a disloyal person operating one of these stations for the benefit of the enemy. In fact one operator on the West Coast made arrangements with a person he thought was an enemy agent and accepted money to transmit messages, but his designs were short-lived when the FBI took him in. Immediately after Pearl Harbor, amateur stations were silenced.

To appreciate the problem confronting any nation attempting to combat the use of radio for subversive purposes, it is necessary to consider the methods available for use by enemy agents which required scientific methods of detection.

After World War I, massive advances were made in the use of radiotelephony. To give some secrecy of talking, circuits were devised whereby speech is rendered unintelligible to those who casually listen in. This mode of transmission in common parlance is "garbled" or "scrambled" speech. Intelligibility is restored only by using complicated receiving equipment and adjustments which must be available to the party endeavoring to reproduce the transmission.

In the meantime, television and facsimile transmission made progress. Here again one must have essentially the same equipment as employed by the sender to reproduce the transmitted image or material. Antennas designed to direct their transmissions to a certain area, with little energy radiated to the sides or rear which could be intercepted or used for direction finding, came into common usage on the part of commercial radio companies and amateurs.

Speculating on other methods which might be used by enemy agents to make it difficult to intercept and locate the transmitter, one must include a multitude of possibilities, some of which are involved and require the most intricate application. Nevertheless, they cannot be discounted and must be considered in any countermeasures plan. The following systems are in this category:

A. Two transmitters widely separated, one of which makes the dots and the other the dashes, or which transmits alternate words, with the signals feeding a receiving system that combines the transmission into solid copy.

B. Transmitters and receivers that change frequency continuously at a synchronized rate during a transmission schedule.

C. Mobile transmitters which move from one place to another, thereby making localization by direction finding and field-strength measurements difficult.

D. Superimposing subaudible or supersonic frequencies upon the carriers of regular broadcasting stations. These frequencies, beyond audibility of the human ear, must be detected by special equipment.

E. Arrangement of broadcast programs and announcements in a prearranged code. This was suspected by certain government officials to be the most general form employed by fifth-columnists to signal submarines relative to the departure and location of ships. This modus operandi is not new; it was employed in Prohibition days to advise rumrunners when the coast was clear and at what point

Lonely vigil: Typical Adcock HF direction finder.

and time they should make their entry.

F. Using diathermy machines for communication. Energy generated in these devices is radiated by the power mains and is capable of transmission over thousands of miles.

Included in this group is the case where the call letters of an established station are pirated by operators of a clandestine circuit to camouflage the operation and appear as officially authorized and registered. This was resorted to by Germany and Japan when they established a radio circuit between Berlin and Tokyo for diplomatic communications that they did not care to transmit through commercial channels.

In planning to combat illegal uses of radio, it is necessary to consider the range of frequencies that might be employed, particularly the ultra-high frequencies for short-distance transmission as, for example, from a vantage point on shore to a ship just below the horizon. The use of these frequencies, while confining the reliable communication range to an optical-path distance or somewhat longer, makes it easy to conceal equipment in suitcases or even on one's body. Interception is accomplished only by establishing a listening station within the narrow limits of the beam. Moreover, a difficult radio goniometric problem is presented, which fortunately was met successfully.

In addition to the technical problems of establishing a monitoring system, another serious obstacle presented itself; a legal problem, occasioned by Section 605 of the Communications Act, which was designed to insure secrecy of addressed communications. At the outset of the war in Europe, the Commission took action against a broadcast station for alleged violation of this provision of the Act, since the station had broadcast as a news item an intercepted radiotelegraph message intended for the German merchant marine.

The action taken in this case was a precedent to which the Commission was forced to adhere as policy in its monitoring operations. The restriction on intercepting or divulging the contents of addressed communications played an important part in espionage activities of the Japanese consul and staff in the then-Territory of Hawaii before the attack on Pearl Harbor.

The report of the Commission appointed by the President to investigate and report the facts relating to this attack includes two paragraphs which read as follows:

> "There were, prior to December 7, 1941, Japanese spies on the Island of Oahu. Some were Japanese consuls or agents and others were persons having no open relations with the Japanese foreign service. These spies collected and, through various channels, transmitted information to the Japanese Empire respecting the military and naval establishments and dispositions on the island.
>
> It was believed that the center of Japanese espionage in Hawaii was the Japanese consulate at Honolulu. It has been discovered that the Japanese consul sent to and received from Tokyo in his own and other names many messages on commercial circuits. This activity greatly increased toward December 7, 1941. The contents of these messages if it could have been learned might have furnished valuable information. In view of the peaceful relations with Japan, and the consequent restriction on the activities of the investigating agencies, they were unable prior to December 7, to examine messages being transmitted through commercial channels by the Japanese consul, or by persons acting for him."

Before December 7th, not a single federal agency responsible for intelligence activities requested assistance from the FCC monitoring system in intercepting radio transmissions from commercial circuits in Hawaii. At that time RID monitoring stations were in operation on the island of Oahu, close to Honolulu; near the city of Hilo on the island of Hawaii; and on Kauai. They were equipped with recorders and direction finders, and personnel diligently performed their tasks to detect and locate any clandestine radio station.

Interior of Adcock DF with BC-221 frequency meter and Hallicrafters SX-28 receiver. Spartan surroundings: storage batteries for power, oil lamps.

Many stories came from Hawaii immediately after December 7 relating to operation of radio stations by enemy agents and to amateur stations operated by second-generation Japanese, alleging they were communicating with Japanese ships and aircraft during the attack. Thorough investigation revealed that these reports were fictitious, as were other fifth-column stories such as cutting sugar cane in an arrow formation pointing to military targets to aid flyers. All well informed military officials agree that the Hawaii incident was carefully planned and rehearsed, and when the aircraft and submarines came in, each knew the location of its target. This was proved when the Japanese plan for the attack was revealed before a Senate investigating committee covering the Pearl Harbor disaster. Because of testimony related to the famous "Winds" message, I was given an official copy of this plan of attack. It was definitely proved that there was no need for the Japanese to use clandestine transmitters prior to the attack, since all the commercial circuits were available and were used by them to get their military information to Tokyo.

Immediately after the attack, as the result of requests from the Army, Navy, and FBI, I took a group of trained men recruited from our stations and with a hold full of equipment sailed in a Navy convoy for Honolulu. While we were off Santa Barbara, headed south to pick up an element of our convoy, a Japanese submarine shelled an oil field nearby. The captain of our ship sent for me early in the morning and showed on the map how close the sub was. He said the first shell was fired while President Roosevelt was making a speech that night.

In addition to our counterespionage operations, locating sources of interference and performing radio-intelligence chores for the Army and Navy, we soon learned of a new and very important use to which our DF network could be put: the location of lost and distressed aircraft by Adcock radio bearings. This new use was really just a by-product of our nationwide system which had been established for entirely different purposes. However, it was a very important by-product.

Suffice it to say that my colleague Ralph Barber, then Major Barber, came to my office and requested help in providing emergency service to the Eastern Defense Command in the manner in which we provided it for the Western Defense Command and Hawaii. It seems Ralph had had the job of escorting his general to Bermuda but the pilot and navigator couldn't find the island and they were forced to return to Mitchell Field. This was not an unusual story for us. We had determined that military aircraft were in some cases flying in the wrong direction, as General Davidson told me in Hawaii a couple of months after the attack. He was soliciting the same service for his B-17s flying from the West Coast to the Islands. He had lost three the night before because of poor navigation. His statement was startling but true: "Production is getting ahead of training."

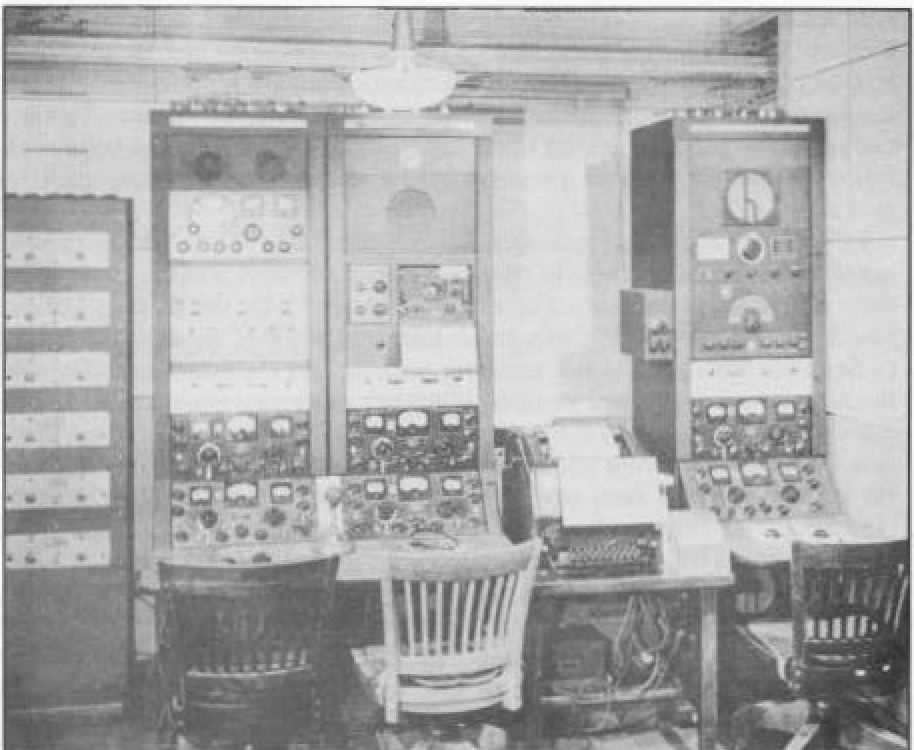
"Eternal vigilance is the price of liberty" was accepted as the order of the day. Through its entire period of operation, RID personnel served with loyalty and distinction as case after case was uncovered of the operations of a worldwide ring of Axis espionage agents with radio transmitters to report the movement of Allied ships, troops, and munitions; the production of factories; the distribution and extent of fortifications and other important military information; and other operations. This information was of great value to our military forces, to the security of the Western Hemisphere, and to the Allied nations throughout the world.

TARGET PRACTICE

In the spring of 1941, reports reached headquarters that there was a station on the air whose operator identified by signing "Fritz" instead of using call letters. A few hours of monitoring revealed that Fritz was endeavoring to chisel in on our own secret radio circuit. It linked the net control station at Laurel with the primary stations. Laurel relayed traffic to Washington through a private-line teletypewriter circuit.

When Laurel would call one of our stations, Fritz would immediately reply by using the tactical call of the addressed station and would advise the operator to go ahead with his traffic. When the traffic was light on our net, he would adjust his frequency to that to the Army Amateur Radio System and communicate with its net control station in Washington. Plans were immediately set in motion to trap him. Cooperation was extended by the Signal Corps station, which kept up an exchange of signals with Fritz to enable our HF direction finders to obtain bearings.

The exchange between Fritz and our own station took on an unusual character. The following excerpts are typical of his transmissions; "I am a cryptographer. You must give me some information in exchange for this stuff. Give me the location of [several U. S. Government station calls]. * * * This station is now in the



Intercept position at the primary monitoring station, Allegan, Michigan. Separate receivers for copying the station under investigation and the control network. At left, transmitters on different frequencies to send encoded alerts to secondary stations, providing them with frequencies and calls.

hands of enemy. Your insolence will not be tolerated by German troops. This station now in control of German Signal Corps. * * * Name here is Hans von Keitel. Heil Hitler. * * * I want your codes and ciphers. Give them to me or else we will jam this net with the big rig. * * * You will be in concentration camp. I am cryptographer for this signal unit in the German Army of Occupation. * * * I am on the Admiral Scheer and never dock." Asked where he was located, Fritz said, "Off the coast of Madagascar."

By keeping Fritz active, bearings were quickly obtained and, when projected, produced a fix close to a midwestern city. Immediately five mobile units were dispatched into the area, each one instructed as to what roads and directions to pursue. They soon picked up the signals and took bearings which indicated that Fritz was located west of the Illinois River, apparently in the city of Peoria. The information was quickly verified by units proceeding toward Peoria from other directions. Subsequent bearings taken from carefully selected sites, free from the influence of overhead wires and buildings, disclosed the location of the transmitter within two city blocks. Close examination revealed an antenna terminated in a delta-matched transmission line on a house within the two blocks, but field-strength readings did not positively confirm this antenna as the radiating structure.

During the evening when it was necessary to do close-in work to determine the exact location of the transmitter, Fritz ceased transmitting since he could not work our station in Laurel or the Army amateur station in Washington. It then became necessary to resort to some special operations. On one occasion on a weekend when WAR was not operating, I authorized one of my engineers, Lou North, to communicate with Fritz from his home in Virginia, using his ham station and signing WAR.

Toward the climax of the case I had sent Ellert, our technical supervisor, to Peoria to offer advice to Supervisor Weston and his staff. Weston believed the transmitter to be in the house with the delta-matched antenna. Ellert was unconvinced and bet Weston a dinner that the station was next door. It was necessary, in securing a search warrant, to state exactly the house, and room in the house, in which the transmitter was believed to be located. To clinch the problem, Ellert requested and got authority to set up a small transmitter in the temporary monitoring station in a downtown hotel room and adjust it to a strength equivalent to the signal received in Peoria from the Laurel and Washington stations.

Because of the character of the transmissions it was necessary to notify the FBI while the station in the hotel room kept up a continuous surveillance. The field agent of the Bureau reported that a thorough investigation had been made of the apparent operator. Permission was secured to obtain a warrant and make an arrest, charging violation of the Communications Act.

Employing the tactical call letters of the Laurel station, the transmitter went into operation as the signals from Laurel started to fade out with the approach of darkness. Fritz took the bait, hook, line and sinker. He continued to transmit while Ellert with special equipment made a positive identification of the site. The operation and that of Lou North back in virginia might be called an entrapment if offered in evidence in court, but quick action was needed.

When an entry was made, Fritz was in communication with what he supposed was a military station and never was advised that the signals that our men heard coming from his loudspeaker were being received from our station in Peoria. The arrest disclosed that Fritz was a college student intent on determining the identity of the stations he heard employing tactical calls and special operating procedure. Only six hours of time elapsed from the date the station was heard until the transmitter was tentatively located. Also only two days passed from Fritz' arrest until he was indicted by a special session of the grand jury on two counts involving Sections 301 and 318 of the Communications Act. Weston settled to Ellert for a dinner.

While operations were in progress on Fritz, another signal had been heard in the amateur seven-MHz band who also called himself Fritz and during one transmission said, "Nuts to the FCC. * * * I am on a ship in the Atlantic and they can't catch me." Bearings indicated the transmitter as being in western Massachusetts.

Because of the nature of the country, a complex DF problem developed due to reflection of signals from the hills. Through arrangements made with the Connecticut Aviation Commission, an airplane was secured and Monitoring Officer C. A. Vimmerstedt quickly determined that the station was located in the town of Haydensville. A mobile unit operating in town almost simultaneously made a

Tom Cave, monitoring officer in charge at the intercept and DF station at Scituate, Rhode Island.

quick determination of the location of the transmitter. Fritz was arrested and later interned in a state institution. John Lamont, W1OJ, participated in this case.

Considerable assistance was rendered by licensed amateurs in New York City and vicinity in keeping this latter Fritz active while field operations were in progress, particularly a young lady operator whom he seemed quite fond of working. This lady ham was our first female counterintelligence operator. Fritz never knew that the W2 he supposed was in the second call zone was actually at the primary monitoring station at Laurel, operated by Charlie Potts under the supervision of Assistant Supervisor "Red" Rollins.

These two cases of radio activity were properly termed "target practice" by our fellows, in preparation for bigger game ahead. They also helped to prove the efficiency of our monitoring and DF system.

SPY AND COUNTERSPY

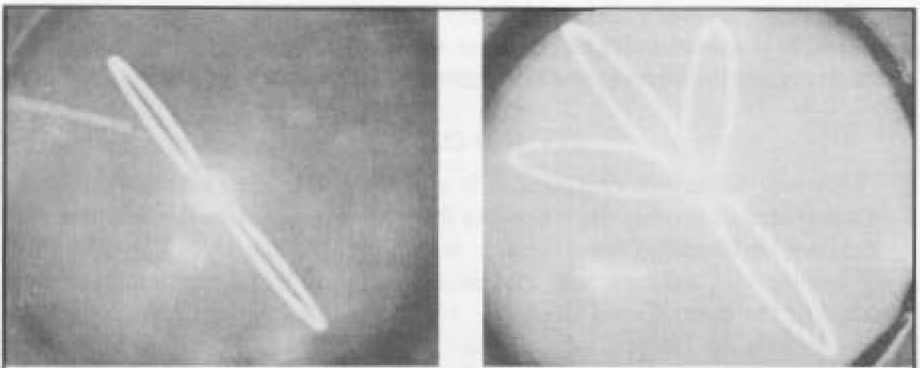
With over 100 monitoring stations in operation, it became necessary to inaugurate a system to process the intercepts that began to flow into Washington, which could not be identified from the aids available at the stations. The use of radio for commercial, military, and diplomatic purposes increased directly with the tempo of the international situation. New call letters and procedures appeared constantly in the intercepted material. New stations appeared on channels assigned to regular stations and their identity could not be found in the official international listings of stations. In looking over the qualifications of those who might provide the nucleus of a specialized staff of radio traffic analysts because of previous service and affiliations, my attention was focused particularly on individuals in stations who provided useful comments on their intercepted material to aid in its evaluation.

One in particular, a radio operator on the staff of the primary station then at San Pedro, California, continually furnished comments suggesting that he appreciated the task we had undertaken in Washington. It should be borne in mind that we were looking for enemy agents with transmitters and had no inkling of the radio procedure they might use. I had ordered this chap into Washington on a detail. While I was busily engaged one afternoon, my secretary announced that a gentleman was outside with no baggage but two hats, one on his head and the other in a hat box.

Thus did Albert McIntosh, formerly of American Airlines, join the staff. He proved to be one of my greatest finds. Others having similar aptitude were located and soon, under McIntosh's supervision, an orderly method of processing intercepted material was in operation. To aid our monitoring staff throughout the nation, I had also assigned him, with some of his assistants, to prepare an identification manual showing the occupancy of the spectrum by callsign, frequency, and type of emission, with samples of traffic and other characteristics. These manuals were to assist in making quick identification of authorized stations throughout the world and thus avoid having volumes of intercepted material processed at headquarters. The necessity of making our monitoring staff familiar with each type of emission and procedure was clear, since the majority had known only amateur procedure or marine traffic. Moreover, the Army and Navy were constantly reporting stations which they could not identify. This was understandable since they had many new operators and officers unfamiliar with non-military traffic.

These manuals became so popular that they were requested by the Navy, Army, OSS, and other agencies. I also had encouraged three of my men to study cryptography, a fair knowledge of which I had acquired in WW I.

During the summer of 1940, RID exchanged information with both Army and Navy about the suspicious operation of two stations operating in the 14-MHz band. One station signed UK and worked another signing AOR. The Navy, with scant numbers of bearings, reported the likely location of AOR as near St.



DF 'scope indications: left, with tight Figure 8 pattern; right, with sense of direction of incoming signal.

John, New Brunswick. While satisfactory bearings had not been obtained, it was believed that UK was located somewhere in west-central New England or New York State.

During this time we were furnishing the Army and Navy with intercepts from UK and AOR and additional intercepts from the British Army and Royal Air Force, and from Japanese weather stations. UK, operating in the middle of the 20-meter band, was heard repeatedly calling AOR and also signed RAY. During August the FBI requested us to furnish intercepts, to which we agreed readily.

On August 31st, J. Edgar Hoover, Director of the FBI, addressed a letter to Chairman Fly of the Commission expressing concern over reports apparently based on magazine articles (notably the "American Magazine") to the effect that FCC agents were daily "raiding" enemy stations in this country. Mr. Hoover stated that he had reliable information that we were cognizant of the activities of station "AOR." It was evident that Mr. Hoover referred to AOR in view of an informal call made only a short time before by one of his representatives. In reply, the Commission stated that we had no specific knowledge of AOR, but that arrangements had already been made to furnish the Bureau with intercepts of it and UK. We indicated that the latest location of AOR was somewhere near St. John, New Brunswick. This, the third report of this location, was based upon a letter from the Navy Department acknowledging receipt of intercepts of AOR and UK and stating the believed site.

On September 17, the Navy advised us that AOR had been tentatively located, that their stations had discontinued watch on it, and they desired no further information from us.

Thus the inability to distinguish between stations not using a standard radio procedure like that of commercial and government stations caused the Navy to drop a task that it initially (and subsequently) regarded as of prime importance. The information furnished us by the Navy was also given to the War Department. We had contacted the latter with intercepts of AOR's transmissions, with other unidentified material our stations had intercepted beginning August 19. In fact the Commission's letter of September 19 to both the War and Navy Departments pointed out that by crossing a bearing of 35 degrees received from our Portland, Oregon, monitoring station with the AOR bearings originally taken by the Navy, an intersection would be obtained in Europe. That is, Portland's bearing gave a desirable wide-angle cut. This type of intersection later became standard procedure in obtaining accurate fixes in Europe. East Coast bearings by themselves tended to be parallel and could not give a precise point in Europe where the station under surveillance was located.

The Navy apparently took no cognizance of the bearing from Portland which we furnished, as the two letters crossed in the mail. The Navy's letter of September 17 apparently closed the case as far as it was concerned.

The War Department responded similarly; in an enclosure from G-2, all intercepts of unidentified stations which we had furnished the Army were returned with a chart "identifying" them. The package included intercepts of both AOR and UK, marked "unidentified." Pencil notes on the bottom of one of these intercepts indicated that a letter count had been made of the text of one of the messages and that the cipher employed was a transposition type. Even so, this traffic did not intrigue the Army to the extent that a solution of the cipher was attempted.

Later we learned that the officer who had made the decision was embarrassed no end because he had had in his possession actual traffic from stations in which the Army was keenly interested but that was not recognized because of the dodge the Germans used in changing call signs. The science of analyzing call-signs, clandestine habits, procedures, and operators' "fists" had not yet been developed to the point where any clandestine message could be easily identified as to source, circuit location, or content.

The Army and Navy, in "closing" this case, left only the FBI as an outlet for the traffic and such other information as we could furnish. By now our identification of radio traffic had reached high proficiency.

On November 11, Al McIntosh noted that the special 4-4-3-3 heading used by AOR and UK contained identical letters in the first group. He surmised that these letters could easily stand for the digits which represent November 11, namely 11/11. Working on this premise during the entire course of one night, the entire system was worked out. Thirty different AOR and UK message headings were exhibited with their solutions. The following morning, armed with this first clue as to how the messages were enciphered, I made the information available to the Navy.

The Navy security officer in charge of cryptography was astounded that such a system was employed but did not recognize it and could not associate it with any type of traffic. Nevertheless this clue caused the Navy to reopen the case. This time much better results were obtained with the bearings because our analysis staff was able to "line-up" the schedules, frequencies, and operations for the Navy in a manner similar to that employed for our own stations. That is, we had learned that we must give our monitoring stations all information possible to help them intercept and take bearings on the desired stations.

It was necessary to describe the characteristics of operators of stations under surveillance and to accurately list the signal styles and sending speeds of each station upon which we desired bearings. With these assists the Navy was able to obtain "synchronized" bearings, that is, bearings that could be positively established as having been obtained on AOR or UK. Matching their results with those we still continued to obtain, an excellent small-triangle "fix" resulted on the

Dorothy Ashley at the secondary monitoring station, South Miami, Florida. Left, taking an Adcock HF bearing; right, plotting the result.

northern end of Long Island.

The only thing that remained was to determine positively what station was sending and its precise location. To this end, the officer in charge of the Naval Communications Security Office requested me to detail McIntosh to his office to assist in solving the UK cipher. He was one of the three I had urged to study cryptography. His analysis had shown that the texts of the traffic were most likely in a German transposition cipher interspersed with frequent null letters. The Navy cryptographers tried desperately to solve it but to no avail. Nor had the FBI given any indication of having broken the code.

I therefore felt that we should not take further time to wait for the reading of the messages, and called the officers in charge of the secondary monitoring stations nearest to the "fix" on UK (namely, Redfern of New York City; Cressy of Portland, Connecticut; and Ross of Bayshore, Long Island) to my office and instructed them on what procedure to follow in determining the exact location of the UK transmitter. By working independently, but exchanging results daily, in three days they were able to locate the exact house in which UK was located. This determination was based upon the projections of groundwave bearings taken by two mobile units on Long Island and one on the Connecticut shore.

On Saturday, December 7, 1940, for the second consecutive day, Ross drove by a house in Centerport, Long Island, and obtained the same result, observing that the Hallicrafters S-29 receiver on the floorboard "blocked" even with the antenna fully collapsed. In addition, Ross observed that this house was the only one in this village of approximately 300 persons with a visible antenna which could conceivably be radiating signals that would reach Germany and AOR on the 14-MHz band.

It was now observed that Centerport was the same village as the one listed as the location of a secret amateur radio station licensed to the FBI in the spring of 1940; this station had been given the call W2NCK for a confidential purpose. It was, therefore, believed that there might be some connection between the license issued to the FBI and the operation of UK. However, the letter from the Bureau answering one from the Commission attempting to determine this information led one to believe otherwise.

Upon consulting with Mr. Jett, Chief Engineer of the FCC and my immediate superior, he advised me to notify the FBI that we had located this station, unidentifiable to the Army and Navy. Unless they had some interest in it, we were going to take action to arrest the operators. I made this information known to Mr. Carson, an FBI supervisor, Monday morning, December 9th. He advised that he would make inquiries and let me know if the Bureau had any interest in the case. He did ask me to await further word before taking any action to enter the station.

Soon after returning from the Bureau, I was called into Mr. Jett's office and was surprised to find Carson waiting to see him. Carson had tried to see Chairman Fly but in his absence had been directed to Mr. Jett. In Jett's office, he stated that the station we had located on Long Island was involved in a counterespionage operation of extreme importance to the FBI. He requested that we take no action against the operators.

This operation reached a climax on June 28, 1941, when the FBI announced the arrest of 33 spies, including three women, and charged them with violating the Espionage Act of 1917. During the progress of this case in Federal Court in Brooklyn, New York, it devolved that they were operators of the station on Long Island. The disclosure came on September 9, 1941, during the testimony of William G. Sebold, a German Army machine gunner during WW I.

Sebold related how he was trapped by the Gestapo while on a visit to his home in Germany after working in the Consolidated Aircraft Company plant in San Diego. Under threat of death to himself and punishment of his mother, brothers, and sister, he joined the Nazi espionage ring. Little did the spy chief, Adolph Fritz Ritter, realize that it was Sebold's firm intention to turn all the information he received over to the U. S. government. After completing a course in the spy school which included radio telegraphy, microphotography, and codes and ciphers, Sebold received instructions to return to the United States. He was to act as paymaster for the spy ring in this country and set up a radiotelegraph station through which the information gathered by the spies would be transmitted to Germany.

The spymaster furnished Sebold with $1,000 cash with which to start activities in America. He was told to operate under the name of Harry Sawyer. He was advised that a spy by the name of Erwin Wilhelm Siegler would aid him in setting up the wireless station. He was furnished microfilms containing all his instructions, the names and addresses of his confederates in this country, and the proper passwords for identification.

Operators of the NDA section of RID recording short-wave broadcasts for the FCC's Foreign Broadcast Intelligence Service. Recordings were translated and analyzed for military and intelligence agencies.

He received a personal message from Dr. Ritter, instructing him to tell Herman Lang of Ridgewood, Long Island, to return to Germany by way of Japan and Siberia. He was told to approach Lang with the greeting "Rentzau, Berlin, Hamburg." Lang, a naturalized citizen of this country and an employee of the Norden bombsight factory, had visited Germany in 1938 and revealed to the German government particulars of the design and construction of this instrument. Apparently the information Lang had supplied was insufficient and the spymaster desired him to return. Lang was reluctant but, even had he desired to, he would have been apprehended by the FBI who had him under surveillance.

Sebold, before departing Germany, had informed the U. S. consul at Cologne of his plans. A representative of the State Department met him when the Manhattan docked at New York and brought him to the FBI office where he told his story and turned over the microfilms and $910 remaining of the money that had been furnished him. He then agreed to enlist in the service of the FBI and operate under their direction as a counterespionage agent.

Sebold himself did not operate the transmitter at Long Island. Instead, the FBI gave Special Agent Morris H. Price this assignment since he was holder of a Class A amateur license and had gained experience operating his own station.

The first transmission made by the FBI operator had taken place on May 25,

1940. The call letters Sebold was instructed to use consisted of the combination "CQ DX V W2" and he was to call AOR. By international agreement each country is assigned certain letters of the alphabet with which to derive call-letter permutations. However, calls beginning with A had not been assigned in any nation at the time. It is believed the German radio minds chose this combination for the reason that it was least apt to attract the attention of our monitoring system and the thousands of licensed operators in the 14-MHz ham band. It is customary for an amateur who desires to communicate over a long distance to make the general call, CQ, and follow it by the letters DX, meaning "long-distance contact desired." In this case the letters DE or V were followed by W2, the prefix for amateurs in the second call area which included Long Island. The Germans failed to add the two or three letters that normally follow after the prefix. However, as far as is known, only one amateur reported the transmissions from the Long Island station as being suspicious during its 15 months of operation. This surprised me since it is often stated that the hams police their own bands.

Special Agent Price made his first call to AOR on the evening of March 15 and continued calling on schedule each day until contact was made on May 22, when the first message was received. It read, "Your signal is very weak. Can you improve it? I will send Tuesdays and Thursdays at 1:00 and 5:00 PM EST - After that they will listen Saturday night and Sunday. Saturday, 12:00 noon OK. Will furnish you new frequency later."

After an exchange of several messages relating to schedules the first business message was transmitted. Sebold had among the spy group Lilly Stein, an artist's model the Germans had sent to New York to collect intelligence from other members of the ring. She advised Sebold that she had new information but needed money, so a message was dispatched to AOR which read "Stein destitute, got new contact but must have money at once."

One of the first important messages received from the spymaster read: "Need urgently from all friends monthly production of airplanes, factories, exports to other countries, especially England and France, number, type, date of delivery by steamer or air; armature and armament; payment cash-and-carry or credit. Rose had $200 for you, not for Stein, greetings."

Later, members of the ring fed information to Sebold in the belief that it was being sent to Germany, not knowing that the FBI was originating hoax messages to keep the Germans satisfied, in addition to other messages relating to payment of funds to agents.

The transmissions continued until September 7, several weeks after the arrest of the ring and four days before Agent Price took the witness stand in court. Apparently Mr. Hoover's men had crippled Hitler's sources of information to the extent that the home office was unaware of the arrest of their agents in the New York area.

A rather dramatic incident was precipitated in court, presided over by Judge Mortimer W. Byers, where 16 of the men accused of espionage activities were on trial. During cross-examination, Agent Price was asked by a defense attorney if he had any way of determining that AOR was in Germany, and he replied that he did not. Moreover he admitted that the transmitter could have been operated from the courtroom and he would not have been aware of it from his station on

RID personnel transcribing tapes of foreign and enemy commercial traffic for use of FBI, Government intelligence agencies, Bureau of Economic Warfare, etc.

Long Island. The defense, with this admission, thought they had scored a major point. U. S. Attorney Harold Kennedy called Al McIntosh of the RID Engineering Department to take the stand.

McIntosh gave expert testimony to prove that the station signing AOR was in the immediate vicinity of Hamburg, Germany. He backed his testimony by charts showing the projections of bearings taken by our primary stations in the U. S. and resulting in a fix on the metropolitan area of Hamburg. Defense attorneys tried to break down McIntosh's testimony, particularly with respect to the accuracy of the bearings and the method of projection. Attorney Kennedy, a former naval officer familiar with charts and bearings, finally led one defense attorney into a ridiculous position where it was obvious to the court that he was in total ignorance of the subject of his examination.

The story of this spy ring and its operation, apprehension, conviction, and sentencing had been covered in the press, in particular by William Gilman in a story, the first installment of which appeared in the November 1942 issue of "True Detective." Gilman gave appropriate credit to the work performed by RID in aiding the FBI in this case.

The details of the story reveal the brilliant operations of the FBI in making moving pictures of the spies' meetings by hidden cameras and keeping each individual under continuous surveillance, resulting in the final roundup of 33, many of whom pled guilty. Of the 16 tried in the Brooklyn court, three received sentences of 18 years. They included Frederick Duquesne, Edmund Carl Heine, and Herman Lang, who had revealed the details of the Norden sight. Duquesne and Heine also received a fine of $5,000. Others were sentenced to various terms ranging from one to 16 years and fines amounting to $1,000 each. Lilly Stein received a 10-year sentence.

Another agent was receiving training in Germany, radio included. It was the intention to send him to New York to set up a radio station with instructions to spy on shipping and report directly to Germany. He came to America by way of Genoa, Italy, and by American steamer to New York. Before departure from Germany he was introduced to a member of the Chicago branch of the German-American Bund. He returned to Germany in April of 1939 and, having run out of money, soon found himself ensnared by the Gestapo. He received orders to proceed to America and, with his training as a machinist, to secure employment in some airplane factory and send reports on production and new-plane secrets. Reuper, one of the New York spies, learned through his introduction to the new member that his name was Alex Wheeler-Hill and that he was related to the head of the German-American Bund in the U. S.

Upon Wheeler-Hill's arrival in the United States, he contacted Reuper who had preceded him to this country and completed arrangements for the construction and installation of a radio transmitter in the former's apartment at 562 Caldwell Avenue in the Bronx. In the meantime, he enrolled in a radio course at the YMCA. Through Reuper he was introduced to August Klein, a commercial photographer who had experience as a radio amateur. With the help of Klein, Wheeler-Hill finally completed his transmitter.

Unknown to him, the FBI had moved into the apartment overhead and were prepared to intercept any messages he sent. Also, our unit in New York City, in charge of Monitoring Officer Louis D. LeFleur, was requested to aid in providing a monitoring surveillance over his transmissions. There has never been any proof that he transmitted a single message that was received in Germany in the short time his transmitter was completed; before apprehension, he never made two-way contact with any station. He did spend his time prowling around the Brooklyn waterfront looking for munitions going abroad. Information secured was sent by airmail via neutral countries, and sometimes by ship courier. Wheeler-Hill and Reuper received sentences of 15 years and Klein, who aided with the transmitter, five years.

Thus ended a series of sensational counterespionage activities. The technical part that RID played in conviction of the accused is just one case in the history of the organization.

THE GERMAN EMBASSY CASE

Before the attack on Pearl Harbor, I had assigned three mobile units in the District of Columbia to provide special surveillance over certain embassies. In the wee hours of Tuesday, December 9, 1941, monitoring officer Morris Blume, in charge of one of the units, radioed my office. (I had slept in my office from December 8, going to a hotel when I could for a bath and a change of clothes.) He reported that his aperiodic receiver had sounded off a strong signal with the call letters UA. With another receiver he identified the frequency and I immediately alerted the other mobile units to guard the frequency and take bearings

German embassy and chancellery, Washington, with antenna poles.

on any transmissions.

I had no sooner done this, than the watch officer informed me that the primary station at Portland, Oregon, had printed on the teletypewriter that it had intercepted a station calling UA and furnished the frequency. It was the same as reported by Blume. I immediately issued orders on the teletypewriter and radio nets for a nationwide alert. We used both nationwide and regional alerts. A short time later, bearings from Adcock HF direction finders started to come into the communication center. They were rapidly projected and made a fix embracing the District of Columbia, with the most intersections in the city of Washington itself. They were followed by bearings taken by DF loops on the mobile units and produced a fix in the vicinity of Massachusetts Avenue at Thomas Circle, the location of the German Embassy. There was no doubt in my mind, then, that the chief operator of the German steamer, Columbus, which had been interned after a chase down the Atlantic Coast, had placed a transmitter on the air in violation of existing agreements concerning embassies. The State Department had permitted the German Embassy to have an operator on duty for what they said was to copy press from the homeland. The staff of the Embassy were in fact sealed in after December 7, deprived of their diplomatic-pouch privileges and commercial channels of communication. On the next transmission we confirmed that the transmitter was in the German Embassy grounds.

I notified the State Department and the FBI after consultation in the early hours of the morning. It was decided that the transmitter should be seized. However, there was a fly in the ointment. There were two buildings on the property, the Embassy itself and the chancellery. A pole on each supported an antenna with a lead-in taken off at each end. I was of the opinion that this was done to make it difficult to pinpoint the location of the transmitter. The FBI wanted me to go in first and, like a quarterback, put the transmitter in their hands. During the conference I told them I could not tell in which building the job was located since it was not advisable to go too close and show our hand.

However, I informed them that, if I could ascertain from the power company that there were separate feeders to each building, switches could be placed in each line and when a transmission was in progress the building could be positively identified by interrupting the power.

It was agreed that this should be done and I got my friend, Mr. Ferris, the Chief Engineer of the Potomac Electric Power Company, out of bed. Before daybreak we were down in a manhole in front of the buildings installing switches. In the end, however, because the State Department was afraid of reprisals to our diplomatic mission still in Germany, it was decided not to enter the buildings but to set up two transmitters to jam signals should they try once more to contact Germany. The jammers were devised by ordering the staff at the primary stations at Millis, Massachusetts, and Laurel, Maryland, to remove the filters from their highest-power transmitters and connect them to the rhombic antennas which were beamed to Europe.

They never tried another transmission. In the meantime we were requested to provide a 24-hour watch over the Embassy. I did this by moving my secretary and her mother out of their apartment since they lived within a block of the buildings. The FBI provided us with the most powerful binoculars I have ever seen, so powerful that they had to be mounted on a tripod. With this instrument and our receivers we did a good job of surveillance.

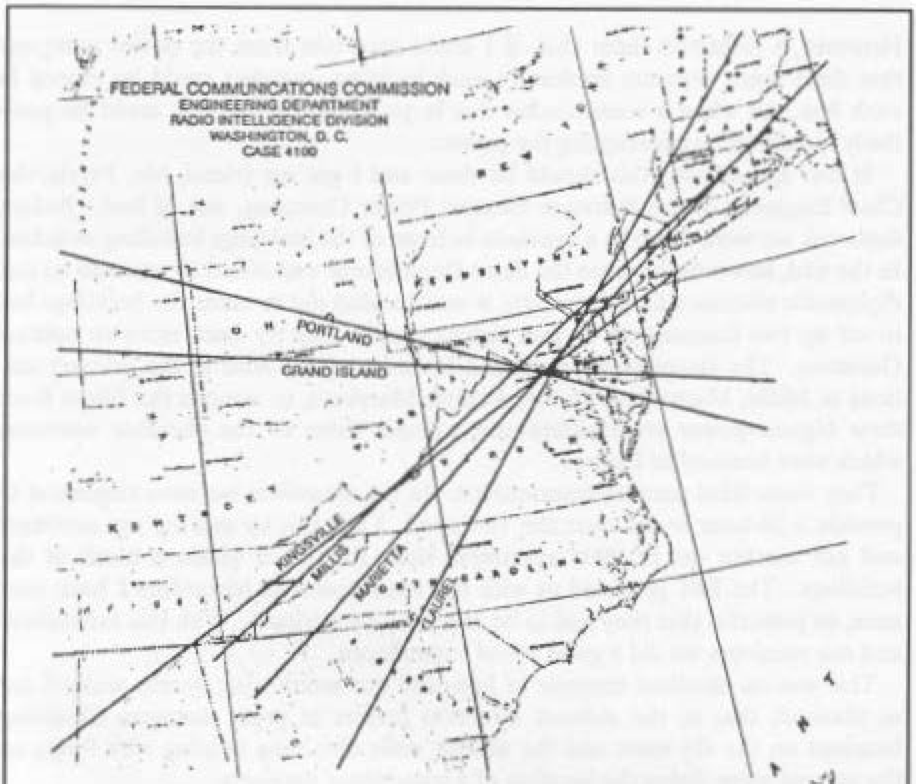
This was an excellent example of how well our monitoring system worked out as planned; that is, the Adcock direction finders at great distances obtaining bearings on the sky wave and the mobile units obtaining bearing with loops on the ground wave, fixing the location of a transmitter precisely.

During 1940 the Treasury Department had said that an instrument had arrived for the Embassy and requested my assistance in identifying it before they permitted it to be delivered. To do this they first told me I had to be sworn in as a special customs officer which was duly performed. I identified the instrument as a Hellschreiber printer, a facsimile system that prints letters and words. I hooked it up in my office and, with only a makeshift antenna, had it printing both German and Russian messages from overseas.

After the war Al McIntosh and I, at the request of the State Department, went into the Embassy and there was the Hellschreiber and other radio gear.

The transmitter in the German Embassy was not the only transmitter RID located in Washington. On August 27, 1942, a station transmitting the call letters VS on 11020 kHz was intercepted by our primary monitoring site at Santa Ana, California. DF bearings from Laurel, Maryland; Kingsville, Texas; Portland, Oregon; and Allegan, Michigan, produced a fix bracketing the District of Columbia.

Having determined that this unknown station was in the District, mobile units were assigned to the case. Loop DF bearings placed the transmitter at the southwest corner of 16th and Fuller Streets, NW. This time it was the Polish Embassy, so the State Department and FBI were notified. In the meantime the operator of the station established communication with what RID located as a clandestine net operated by the Polish government in exile in London and Montevideo, Uruguay. Bearings taken in Hawaii and Puerto Rico, combined with those taken from our stateside stations, helped confirm the locations of these three stations.



Bearings from monitoring stations around the nation.

We were concerned about the operation of this transmitter in the Embassy since, while it was under surveillance, a message was transmitted in English advising about the weather in the District of Columbia and vicinity. This type of information violated our censorship regulations. The transmission of weather information in the U. S. could have been of valuable assistance to the German High Command in the event they were planning to strike the United States by an air attack. Soon after the transmission of this information the station was silenced by our Government.

RID had at this time located two Nazi weather stations as close to our continent as Greenland, which the Coast Guard subsequently destroyed.

A CANADIAN CASE

At one stage of the war an intercept was made of a signal having many of the characteristics of the Nazi espionage system. A nationwide alert brought in bearings that produced a wide and somewhat erratic fix embracing part of Canada and northern New York State. At that time propagation conditions were very turbulent. We implored the monitoring stations for bearings but some days produced none. We were unable to determine whether the transmitter was in the U. S. or Canada. It must be remembered that HF direction-finding is not an exact science. The best it can do is to give the direction of arrival of the radio signal, which may be diverted from its true course by propagation turbulence or site errors. In the meantime I had dispatched three mobile units, hoping that they could get within the ground wave range of the signal, a small area at the frequency the station was operating on, and thus pinpoint the transmitter with loops. After several unrestful days and nights, propagation became stable and a fix of sufficient reliability was obtained to convince me that the transmitter was in or near Montreal. I telephoned my counterpart in the Royal Canadian Signal Corps, Colonel Drake, and informed him of our conclusions.

A few days later he informed me that we had done much to permit him to save face. The story was that a German submarine had landed a spy in the St. Lawrence River. He was quickly apprehended by the Royal Canadian Mounted Police. They, like the FBI, were responsible for investigating acts of espionage and sabotage.

Accordingly they had set up the transmitter brought by the German agent and were attempting to use it as a counterespionage operation, similar to the FBI case on Long Island. So Colonel Drake's crew went to work and quickly located the transmitter and he in turn expressed gratitude to RID since it was unnecessary for him to disclose how he had first heard about the operation of the station.

NAZI SPIES IN LATIN AMERICA

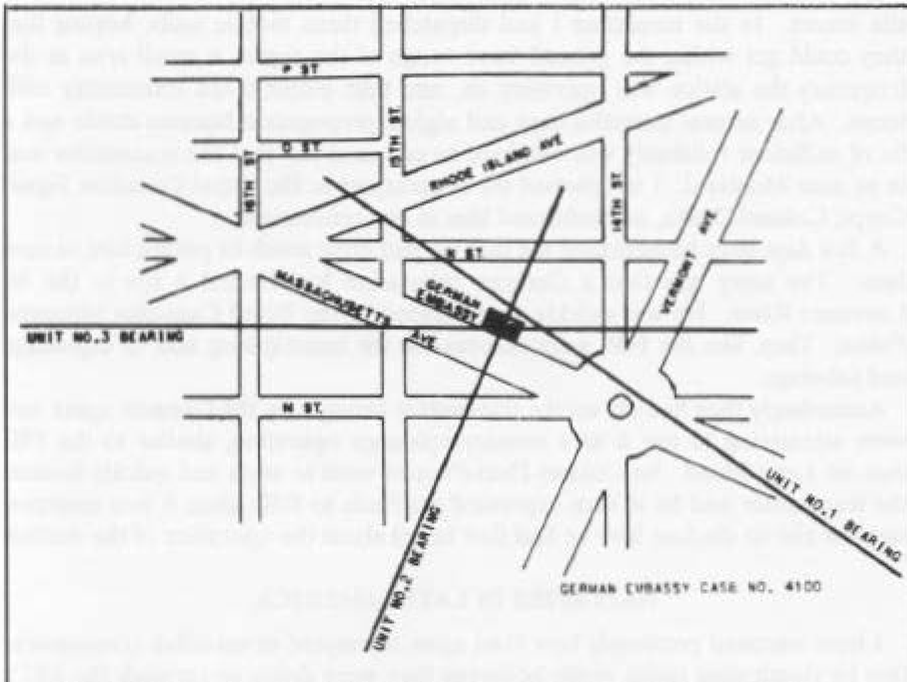
I have narrated previously how Nazi spies attempted to establish communication by clandestine radio, really believing they were doing so through the FBI's transmitter on Long Island. Alex Wheeler-Hill's attempt was a similar unsuccessful effort.

So, with the closing of the German Embassy case and this one in New York, no other station engaged in espionage successfully within the U. S. to the best of our knowledge. This was the beginning and the end for Axis radio agents within our borders. German agents picked up by the FBI thereafter were found to have been using secret ink or microfilm through mail drops to get information out of the country. We learned that some Japanese agents who requested funds to establish a station on the West Coast were turned down on the grounds that RID would nab them as soon as they got on the air.

Wilhelm Hoettel, one of the German foreign intelligence area chiefs, affirmed during his interrogation by the Third Army in June 1945 that the Sicherheitsdienst (SD) had been unable to establish a single radio connection with the U. S.

However, outside our borders it was a different story, one in which RID became intimately concerned. While we could take pride in having sealed the United States against espionage transmission, we could take no comfort from the fact that they had set up shop in Latin America. There spies had ways of getting information from the U. S., including the use of travelers and invisible ink. Once they had that information they could shortwave it to Germany. These nations had virtually no facilities to combat such activity and in fact were largely unaware of it, since they had no adequate radio intelligence. But we of RID were painfully aware of the scope of espionage activity in the Good Neighbor countries. Our long-range finders located station after station sending out a shocking flow of intelligence. Often they intercepted the stations before they could establish contact with each other.

Signs of the Nazi effort to create an espionage base in Latin America were ap-



Projected loop bearings taken by three mobile units within ground-wave range of Washington.

parent as early as the fall of 1940. On October 27th, our primary station at Allegan, Michigan, picked up a strange maritime signal using the unregistered call BCNL. Other monitoring posts were alerted and quite a number of similar calls were traced to ships in the Gulf of Mexico and the Caribbean Sea. Our Tampa office succeeded in identifying these vessels as small ones operated by a firm near Belize, British Honduras, which also operated a small coastal station. The U. S. Caribbean Defense Command, after developing evidence that this fleet was being used to refuel German submarines and passing information, arrested a Canal Zone employee who was a member of the ring and was able to arrange a trap for 19 others, including the ringleader, a prominent shipping executive I believe.

The concerted drive to establish radio-agent nets in this hemisphere and our struggle against them began in the spring of 1941. Our monitor at Millis, Massachusetts, detected the faint signals of a station trying to hide its transmission in a transatlantic circuit operating on the same frequency. It was repeating the call letters REW, but the signal sounded quite like that of the German AOR.

Other monitoring stations were put on the case to help identify the suspicious signal and copy all transmissions. It was noted that when REW paused to listen, a station on a different frequency would start sending the call letters PYL. The two transmitters put on the same performance at the same hour the next several days in their apparent attempt to contact each other. Grainger, the officer in charge of our station at Searsport, Maine, became so enthusiastic about the case he requested that I permit him to tune up his transmitter on the frequency of one of the stations and help them get together so we could intercept the traffic.

In the meantime all HF direction finders had been alerted to the case. As bearings came in, the fixes showed that REW was in Hamburg, and PYL in Valparaiso, Chile, an espionage station discovered before it could contact its base.

As our monitors patrolled the ether, more and more clandestine transmitters were identified and approximate locations determined. Chile and Brazil held the principal concentrations at this time. There were three main agent networks in Brazil, centered on transmitters that we designated LIR, CEL, and CIT from the callsigns used when first heard. Evidence of the damage, the messages sent from these transmitters began to mount.

Before revealing the contents of some of these messages, I think it would be well to digress for a bit and explain how the espionage system operated and how the agents were trained.

THE GERMAN RADIO ESPIONAGE SYSTEM

The German espionage system used six major radio nets with control centers in Berlin, Hamburg, Bordeaux, Madrid, Paris, and, at one time, Lisbon, for the purpose of securing information relating to the movement of Allied ships and troops, armaments, production of factories and other essential information. The radio stations associated with these control centers extended to practically every country in Europe, neutral countries in Africa, islands in the Atlantic, and the Western Hemisphere. Berlin controlled the largest net.

The following is how the agents of the Nazi espionage system were trained. This picture has been assembled largely from interviews and confessions of agents whom we assisted in running down.

Ordinarily, the training took place in a school near Hamburg. The men selected for these assignments were not skilled radiomen. They were taught photography and microfilming, use of invisible ink for secret writing, codes and ciphers, radio, handling of explosives, demolition methods, and other essentials.

As part of their radio training, candidates for this service were taught International Morse Code, construction and use of transmitters and receivers, and general radio knowledge. Prospects had to pass a test in sending, transmitting 50 to 60 letters per minute, equivalent to 12 words per minute.

After they finished training, each candidate was required to send for five minutes with special equipment, producing a graph indicating his touch, speed, and method of sending. The person in charge, after studying this graph, assigned the agent a sending speed. The student was required thereafter to transmit all messages at the assigned speed. In order that he be properly trained into this speed, he underwent further practice in sending only. At the conclusion of the week, another graph was made for reference. Having a record at the control center of the agent's individual sending characteristics was a protective measure to insure that the transmitter was in fact being operated by their representative and not an operator of a counterespionage agency. This action was taken, I believe, after the Nazis had been fooled by the FBI's countermeasure on Long Island.

An agent was provided a portable station, generally built into a suitcase and complete in itself, including antenna wire, tools and all accessories to activate the station quickly at its destination. (I was presented one of these suitcase jobs by the Brazilian government in appreciation for the work RID performed for it.)

RID chief Sterling and his assistant Albert McIntosh inspecting equipment in embassy after the U. S. government took over the buildings from Swiss officials.

I have mentioned that these agents, while in training, received instruction in codes and ciphers. One group of agents was taught to use a system which utilized popular novels for the purpose of securing call letters as well as enciphering messages. The system of call letters used and the manner in which they were derived is of interest. In this group, the call letters of the control station in Germany and the agent outside changed daily. Let us examine a particular case which requires the use of the novel "The Story of San Michele" by Alex Munthe, published by the Albatross Publishing Company of Leipzig, Paris, and Bologna. On the front cover will be observed the copyright notice "Not to be introduced into the British Empire or the U. S. A." This novel was used not only to arrive at the daily call letters of each station but also to encipher and decipher messages. Each agent was assigned a certain constant. The agent added to this constant the number of the year plus the day. In the case at hand the constant was 56. In selecting the calls to be used for a particular date, as for example June 6, it was necessary to add the number of the day plus the month to the constant, which in this case would be 12 plus 56, giving a total of 68. This operation gives the number of the page of the novel to be consulted. The call letters come from the bottom line of this page as follows: the first three letters of the first word on the bottom line, read in reverse order, give the call for this date for station No. 1, which is the control station in Germany, the "in" station. In similar manner, the last word on the bottom line, when read backward gives the call for station No. 2, the espionage or "out" station.

Let us turn to page 68 of this novel and see what we find. The last line reads: "half open door he wagged his stump of a tail and looked." If we take the first three letters of the first word of this line and read them in reverse, we find the call of the control station LAH, and since the last word on the line is "looked," the last three letters when read backward give the call letters DEK for the "out" station. On the succeeding day, page 69 will be used for this purpose. This would continue until the end of the month, after which the process would start over.

By careful analysis of traffic intercepted from agents' stations, RID had been able to work out in advance the call letters which were to be used on many clandestine circuits each day. These were furnished our monitoring stations for the purpose of identifying the transmissions. This information had also been given to other interested agencies, as for example, British Security Coordination and the Coast Guard. Sometimes as operator was caught making a mistake by not using the call or frequency required by his own system.

It became necessary on one occasion for a clandestine station to use the call letters "SOS," which everyone recognizes as an international distress signal. This was in 1941 when there were many who were listening on the shortwave bands. In cases of this kind it is customary for operators of government agencies and shortwave listeners to report such transmissions to the FCC. Anticipating such reports on that date, a memorandum was furnished all RID monitoring stations and inspectors in charge in the Field Division so that they could handle the situation properly.

Another very common system of call letters employed on certain intraEuropean circuits was the "odd-even month" method. This type consisted of two sets of 31 calls each, the first set being used during each odd month and the second for each even month. Obviously, in such a system the same call would be used on the second of January, March, May and July. A variation of this type of call was used by stations which employed only one list, the same call being used for the same day of each month throughout the year. There were a few circuits which used a different call for each day.

The control of one of the most important clandestine nets in the Western Hemisphere passed from the German High Command to the German intelligence agencies. At that time the net adopted call letters and frequencies assigned to commercial stations located in South America. This made detection more difficult but it was still possible to identify the traffic by the formulation of the messages and the general operating procedures which were characteristic of German clandestine stations. Thereafter, the procedure was changed and this net used a call list based on the "month plus day" system.

RID did not maintain a cryptanalysis laboratory, but, in order to be able to identify traffic, RID did have a handful of men who became familiar with such work.

The German espionage operators used the signal "QSO zero" when either the "in" (control) station or the "out" (agent) station was attempting to establish communication. On occasions RID operators knew a new agent was to come on the air since they could hear the control station calling each day with a different call letter and ending "QSO zero please answer." The agent would also terminate his call in this fashion until contact was established. "QSO zero please answer," became quite a big word among the RID boys.

I previously explained how Nazi espionage systems used novels to enable them to encode their messages, novels not normally obtainable in the U. S. or the British Empire. Let us see how this system of cryptography worked in a real case.

Shortly before 8 AM on March 12, 1942, a monitoring officer at the secondary station at Laredo, Texas, copied solid a 35-group coded message on 220 kHz. He really had to dig it out of the mud since it was sent with one of the low-powered suitcase transmitters. The sender signed the call letters EVI. We knew from analysis of previous messages that the call EVI was due to be used by an operator of the San Michele group whose assigned constant was 56. Checking, we added the month and day. This would be March 13 by GMT, so we turned to page 72 of the novel. The last word on the page is "give" so EVI is right for that day. The first word on the last line is "like," hence the control center call letters for that day are KIL.

Now if we decipher the coded message in accordance with the prescribed procedure, we obtain a German text which, translated into English, reads "Sixty from [agent] Vesta to Stein, Queen Mary reported off Recife by steamship Campeiro on eleventh at eighteen o'clock middle European time." On that day three of the six espionage transmitters in Rio reported the arrival of the Queen Mary.

The Queen Mary laid over in Rio de Janeiro for about a week and took aboard a considerable number of troops. A few hours after she sailed on March 20, 1942, the Brazilian police rounded up a number of German spies, including a leader by the name of Christiansen, whose organization was operating in Rio, Recife and other places in Brazil. In a few days they had rounded up some 200 espionage agents.

The last message to Hamburg had reported the movements of the Queen Mary. However, the British Naval Attache had been promptly advised of the espionage transmission. This enabled the Admiralty to change the Queen Mary's route. RID had first detected the activities of the Christiansen operation (known as the CIT group), as well as the LIR and CEL groups.

During this period the control stations sent exhaustive lists of requirements for information, asking PYL in Chile if they could "place a suitable man for us among students going to the United States for air training," complimented agents as "exceptionally correct" in their reports on technical details of English and America cruisers' equipment, and assigned agents to investigate "USA parade and air bases in Columbia and Venezuela" and "air units in Trinidad and Lesser Antilles and flights via those places to West Africa, airplane types, movements, dates." The agents sent back reports like these:

> "5 July. Nine Boeings flew with mixed crew English and Americans. In next few weeks 20 more to be flown across. Details follow.
>
> 19 July. LM reports 15 Lockheed Hudsons flew across. English registry and Canadian-Australian crew. Boeing Clipper left Natal on seventh allegedly for Boland with 19 Lockheed mechanics and 11 crew.
>
> 7 August. USA steamer Uruguay on last voyage to United

States left Rio 25 June. Was convoyed by British auxiliary cruiser Carnarvon Castle to Trinidad. Trip takes 7 days. Cruiser traveled sometimes ahead sometimes astern of SS Uruguay.

8 October. BMM reports several hundred US aircraft of various types and 8000 special troops allegedly landing corps being assembled Port of Spain.

1 January. Curtiss Columbus factory will begin mass production series SB2C single seater stuka ["stuka" is a general German acronym for "dive bomber"] for Navy. Armament one cannon, five machine guns, motor 1700 HP Wright. Built for 2000 HP Wright in experimental stage. Production SO3C begun in Columbus factory at beginning December. Employees all Curtiss aircraft factories December total 27000. Propeller production November 1042."

THE AMERICAN REPUBLICS PREPARE FOR ACTION

The Emergency Advisory Committee for Political Defense, representing Latin American nations and the United States, published a report at this time which stated "The pernicious and constant activities of the German spies are proved by hundreds of messages intercepted by an agency of the Government of the United States of America * * * by means of detecting equipment in that country." This state of affairs as revealed by our monitoring stations aroused the Latin American nations to action.

The third meeting of the foreign ministers of the American republics on January 15, 1942, 39 days after Pearl Harbor, adopted a resolution recommending that the several governments take immediate measures to eliminate clandestine stations. Accordingly, at the request of the State Department, RID sent monitoring officers and equipment to our neighbors to the south and trained 30 of their representatives in radio-intelligence theory and technique at our school at Laurel.

At the end of the course these trainees were required to locate hidden transmitters in the surrounding countryside, sometimes 15 to 20 miles away. One phase of this exercise required that the first bearing be taken on the DF loop with which the cars were equipped. These were plug-in loops, concealed except when taking a bearing. After plotting the bearings on a chart, the students were required to take off and procure at least two more bearings so as to obtain a fix.

While the engineers from Latin America were training under direction of my technical supervisor Charles Ellert, the RID men we had sent were busy helping their governments locate espionage transmitters and establish monitoring networks after that of RID.

The man we sent to Brazil was Robert D. Linx. He helped lay the groundwork for the spy arrests after the Queen Mary left her dock in March. Much of the equipment seized in the arrests, other than the suitcase transmitters, was manufactured in the U. S. It was the same as we were using in counterespionage.

These roundups apparently cleaned out the LIR and CIT organizations, as they were never heard on the air again. Some members of CEL escaped to the

RID agents preparatory to leaving for South America with RID chief Sterling and officials (not identified) from the State Department and FBI. Left to right, standing: John M. Larson, CIAA; Benjamin Theeman, CIAA; Charles A. Ellert, traveling supervisor, FCC; Elliott S. Hanson, administrator, Inter-American Training Administration; Glen W. Earnhart, Paul S. Means, Donald E. Strong, Charles R. Weeks, William N. Fellows, Dale B. Dorothy, Sidney R. Lines, John W. Crews; Capt. William L. Calfee, Military Intelligence Service AIC; George N. Butler, assistant administrator, Inter-American Training Administration; R. E. Thornton, special agent supervisor, FBI; Stacy W. Norman, assistant to Mr. Sterling.

interior. They ventured twice to get their transmitters on the air but arrests put an end to them also.

It was not until August of 1943 that Nazi agents again attempted to use radio in Brazil. About midnight on August 9, two agents were landed at San Joao de Barra, Brazil, from a German fishing vessel. They were apprehended immediately by the police. These two carried with them two shortwave transmitters, with which they were to send intelligence to Germany. With the aid of Bob Linx, one was placed in operation as a counterespionage station under the auspices of the Brazilian Army. One of the Nazi agents was used as an operator and communication was established with Germany.

During the operation of this station, the control station sent a message asking about the defenses of the harbor of Rio de Janeiro, the locations of submarine nets and mine fields, as well as the arrival and sailing dates of vessels. The Brazilians thought that this communication might indicate that the Germans planned a token invasion of the harbor and city of Rio. In reply, a message was sent to the Reich in the hope of laying a trap of some kind for a U-boat.

Subsequently, through the facilities of this counterespionage station two messages were received from Germany:

"Information is desired concerning the strength and composition of the Brazilian Air Force. What possibility is there of being sent abroad?"

"Impossible to give you any contact in Rio de Janeiro. As last extremity, proceed to the south and contact the individual whose name you already have."

From the last message we concluded that with the help of RID the German spies in the various cells operating in Rio and vicinity had been cleared out or silenced. Subsequently the Brazilians abandoned use of this counterespionage station; however, RID monitors in the U. S. heard the control station in Germany trying to contact it long afterward.

The suitcase transmitter and receiver presented to me by the Brazilian government was one of those carried by the two agents who landed at San Joao de Barra.

By mid-1944 Brazil was permanently cured of its radio spy infestation. Bob Linx stayed on to direct the establishment and operation of Brazil's monitoring service, patterned after that of RID, as the "father of Brazilian monitoring."

RID AIDS THE CHILEAN GOVERNMENT

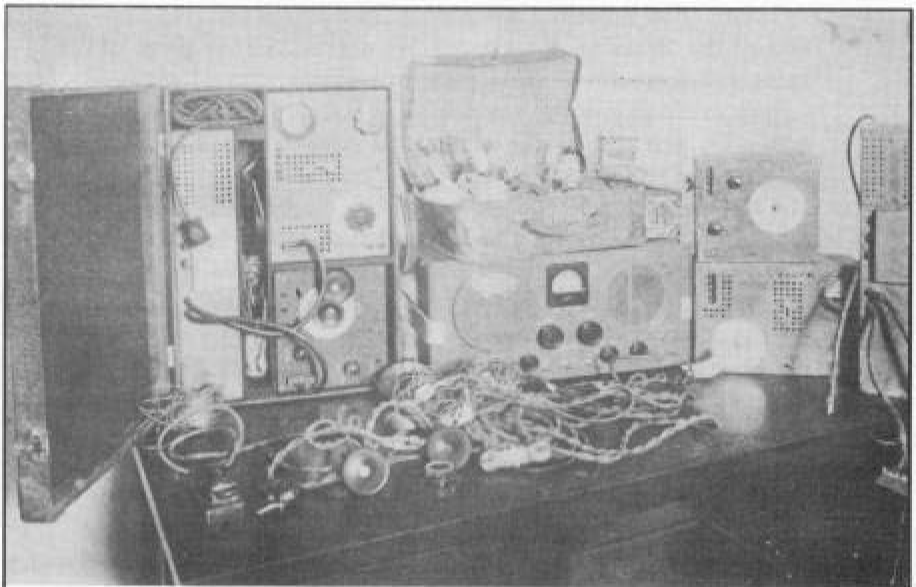
I have previously indicated the kind of information the German espionage headquarters in Berlin was demanding of its agents in South America. The initial call letters of the station RID first detected in Chile was PYL, so we always identified the Chile operation by those call letters.

The man we sent to Chile in 1941 was John F. de Bardeleben. Before his arrival we had intercepted and decoded a message PYL sent to Hamburg, that their agent "Pedro" would be ready to test on the next day, March 9, an auxiliary transmitter for PYL, made from parts purchased by Nazi agent Blume. On March 10, RID monitors in the U. S. picked up Pedro's test transmission the first time he attempted communication with Germany. He signed the call letters GES.

John de Bardeleben arrived in Valparaiso on March 19. This was the signal for the main transmitter of PYL to be moved around. He spent weeks tracking its changes in location within a ten-mile radius of Valparaiso. It was noted that every second week, however, a transmission would be made from a house at Avenida Alemana 5508, Cuso Alegre. [Ironically, "Alemana" means "German" in Spanish.] This house was owned by Guillermo Zeller, a radio technician and licensed amateur who was often seen in the company of Blume, manager of the Valparaiso office of the German company Transradio.

In April of 1941, shortly before PYL was first heard trying to contact REW, Blume had bought two receivers and a complete set of transmitter parts from a local supply store. A tap was then placed on Zeller's telephone. The Chilean police prematurely raided his house on June 25th. Their perfunctory search revealed no transmitter. De Bardeleben told me that he believed Zeller had been tipped off. Another raid was made after Zeller had telephoned his agent colleagues and reported he had a narrow escape since the police had not made a good search. He had his transmitter in a sewing-machine box.

PYL went off the air after this and nothing could be done, but a few weeks



Equipment from Italian spy ring, used in Rio de Janeiro, Brazil, to communicate with Rome. Suitcase transmitter and Hallicrafters receiver.

later de Bardeleben found the transmitter in the sewing-machine box in a store on the same street on which Zeller lived. Most of the agents of the PYL organization were finally arrested on October 23rd, but the man who actually operated the main transmitter, "Pedro," had disappeared. In the meantime I had sent de Bardeleben with another agent to Argentina.

William Fellows, one of the RID engineers who had developed our aperiodic receiver, was sent to Chile to take de Bardeleben's place. Almost a year after the incomplete capture of the PYL ring in Valparaiso, three operators at widely scattered monitoring sites intercepted a new station with the call letters PQZ. All three stated on their intercepted copy that the fist of the operator resembled that of Pedro, who had signed the call GES when using the standby transmitter made of Blume's parts. An alert on the RID monitoring network obtained bearings on PQZ during his next schedule. The fix indicated Santiago.

Fellows immediately sent orders to track down the location of PQZ. Because of short communications, he had a difficult time obtaining enough bearings to produce a good fix on the house in which the transmitter was apparently located. One night, while doing a little footwork in the area he had bracketed with bearings, and long after the lights had gone out in surrounding houses, Fellows detected a trace of light seeping through a corner of a window on the second story of the house. In daylight the next day, a discreet investigation revealed a small wire running from the window to a tree in the near yard. Now the pursuit was getting hot.

Fellows played the game carefully. When the signal next came on the air, bearings confirmed the location of the transmitter. So, to my considerable satisfaction, the operator Pedro, a graduate of the Hamburg spy school who had been hiding for a year, and who also had the effrontery to use my own initials for call letters (!), was arrested and his equipment seized. This case was an excellent example of the proficiency of RID operators since three of them, at widely different locations, advised that the operator signing PQZ had the same fist or sending style as one who had operated GES a year before. Yes, indeed it was Pedro.

The following are typical of the decoded messages sent between Hamburg and Valparaiso by the spy ring in Chile and the control in Hamburg.

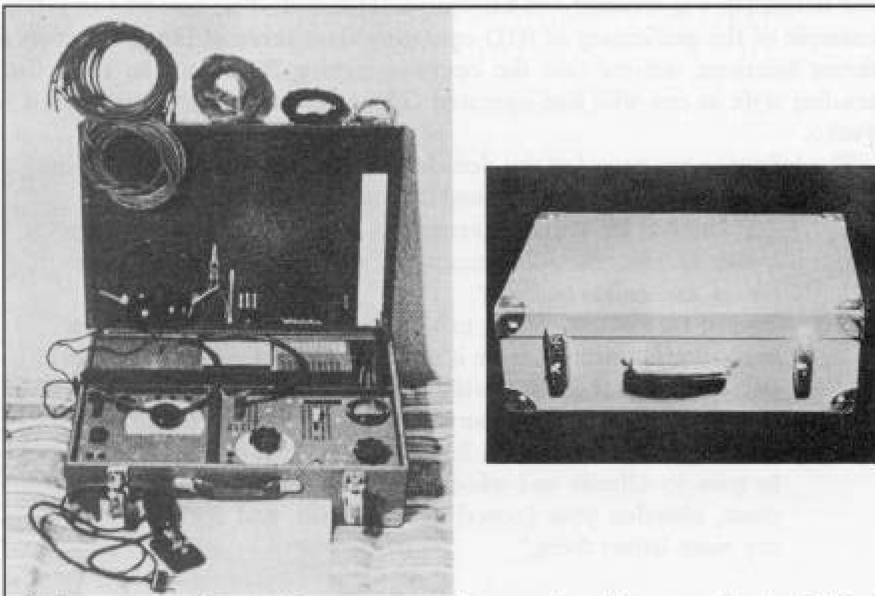
> December 15, 1941, Valparaiso to Hamburg, "Please develop letters to Senorita with signatures Pedro, Alfredo, or Roberto for ink and radio contents."
>
> April 14, 1942, Hamburg to Valparaiso, "Give up Luis as soon as connection with Enrique is secured. Collect mail meanwhile only by means of a trustworthy middleman."
>
> March 26, 1942, Hamburg to Valparaiso, "Be careful. Alfredo arrested. Please ask Bach which of your cover addresses he gave to Alfredo and whom Alfredo passed it on to. In any event, abandon your [cover] address Juan, and don't pick up any more letters there."

ARGENTINA - HOTBED OF GERMAN ESPIONAGE

It can be seen that Argentina was the center of German espionage operations in the Western Hemisphere from the following quotations reported in January of 1943 from the Emergency Advisory Committee for Political Defense to the governments of the American republics in Resolution XVIII on the subject of Axis espionage activities.

This resolution said in part:

> "A. The Government of the United States of America has submitted to the Emergency Advisory Committee for Political Defense, for its consideration, a memorandum dated Jan. 4 of the current year, entitled 'Axis Espionage Activities in Argentina';
>
> B. This memorandum reveals the existence of well organized and extremely active groups of Axis espionage agents who are using one of the American Republics as a base of operations against all of the Republics of the American continent, in flagrant violation and disregard of the most elementary standards of conduct between nations which maintain friendly relations;
>
> C. This document further reveals that these espionage groups are organized, directed, and financed by German diplomatic representatives accredited to the Argentine Republic, who have also undertaken the organization, direction, and coordination of the different groups or cells of agents and their accomplices, engaged in subversive activities in favor of and for the totalitarian states, so that these diplomatic representatives constitute an integral part of the German espionage system, operating in America under the orders and instructions of the German High Command."



Suitcase transmitter. After capture, unit was placed in operation by RID officer Robert Linx to establish contact with Germany. Later presented to RID chief Sterling by the Brazilian government.

Resolution XVIII goes on to state:

"The information demonstrates that after the rupture of diplomatic relations with the Axis by various countries, the Axis began to use Argentina as the base of its espionage and sabotage activities against all the American nations. It has been established that from this base of operations the Germans have spread the net of their subversive organization to at least ten American countries, and that as a result of their work a large number of American lives, considerable American property, and the lives and property of the citizens and countries of the United Nations which are engaged in the struggle against the totalitarian power have been lost.

Totalitarian diplomats and agents have employed every imaginable artifice and technique to achieve their objective of undermining and destroying the defense and security of the peoples of the American Republics. In addition to the methods already mentioned - that is to say, espionage, the transmission of information by diplomatic channels, clandestine radio, the mails and telecommunications, secret ink, etc. - the following may be cited, among others, written and oral propaganda, sabotage, clandestine entry and exit, either by secretly crossing frontiers that are not under patrol or by using fraudulent passports, certificates or other documents of identity, and abuse of nationality.

A number of ranking espionage agents enjoy diplomatic sta-

> tus and are actually connected with the German embassies. This is especially true of the military and naval attaches. * * * some of the principal espionage agents are Nazi party leaders and known as such. The German embassies have not hesitated to use clandestine radio stations and it is definitely known that the German embassy in Rio de Janeiro employed a station * * * in sending messages to the Foreign Office in Berlin."

Since Axis agents could send unlimited coded messages through regular commercial radiotelegraph and telephone circuits, by diplomatic pouch, and by secret writing, they had no need for clandestine radio stations. However, after the exposure of the situation in Brazil, Chile, and Argentina, the Argentine government restricted the number of coded messages that could be sent through commercial radio and cable circuits and eventually prohibited them.

These restrictions forced the Nazis in Argentina to resort to clandestine radio. RID direction finders in the U. S. established the location of several near Buenos Aires. The traffic with Germany was copied daily and furnished the appropriate agencies of the government as soon as received. Moreover, the Germans sent traffic by one-way naval circuit from Germany to their embassy in Buenos Aires.

During December 1943, RID intercepted coded messages containing 10,000 five-letter groups. On April 17 a station in Argentina sent 2,325 groups, establishing a new record for espionage traffic from that country for a single day.

During May of 1943, the State Department requested that the FCC help Argentina locate these clandestine transmitters. Two RID men, de Bardeleben, who had performed meritorious service in Chile, and Francis McDermott of the departmental staff, were given this assignment.

Our men experienced considerable difficulty in Argentina because of the political situation. All automobiles were under strict surveillance by the police, especially those which operated outside of Buenos Aires. This hindered their field operation. Sufficient evidence was gained, however, to confirm the existence of at least six transmitters. The Nazi technicians resorted to every trick of the trade in order to prevent being located. They would operate a transmitter at a certain location one day and when our men would move in as a result of DF bearings, they would find that on a following day the transmissions were made from a transmitter many miles away.

I was informed that the radio operators of the interned German crew of the Graf Spee aided the embassy in its clandestine radio operations. It was only by careful analysis of the "fists" of the operators and technical aspects of the emissions that we were able to determine exactly how many transmitters were in use.

At one time, the German High Command was transmitting information "blind," that is, one-way, to the German embassy by means of the Hellschreiber system, which prints on tape the letters of the message. It was fortunate that RID had equipment to intercept and print these transmissions, since the Coast Guard Cryptographic Laboratory of the Navy Department needed the intercepts urgently.

Through information obtained from the U. S. embassy and its contacts, as well as by monitoring, we concluded that no transmitter was being operated at the German embassy itself. However, a store of radio parts was kept there, includ-

Another group of clandestine equipment located by RID in Rio de Janeiro, January 20, 1942.

ing parts which were used in transmitters with the call letters LIR and MAX in Brazil. The embassy forced the Argentine police to return these parts after the trial and expulsion of the naval attache, Captain Neibuhr, who was deported to Germany after his espionage work in Argentina.

Finally, when the Argentine situation took a turn for the worse from the Allied standpoint, the State Department decided to withdraw our men and store the equipment until such time as the full cooperation of the Argentine government could be secured in suppressing clandestine stations. In fact, the Argentines were about to charge our two men with espionage. On the advice of the State Department, we had to get them out the country in a hurry.

OPERATION CUBA: A SPY IS EXECUTED

On March 21, 1942, Acting Secretary of State Sumner Welles addressed a communication to Chairman Fly of the FCC, which stated, "My attention has been invited by the authorities of the Cuban Government to the urgent and critical necessity of discovering and suppressing a number of clandestine radio transmitters which are now conveying information to enemy submarines concerning the movement of merchant vessels on the coast of Cuba. * * * I should, therefore, appreciate it if you would be good enough to inform me whether the Federal Communications Commission could make available immediately a mobile direction finder detecting apparatus."

In accordance with this request, Mr. Charles B. Hogg of RID was detailed to

Cuba, arriving during the latter part of April.

Hogg discovered that a group of nine stations was being operated by an official of the Cuban government without authority and that messages were being exchanged relating to the movement of vessels and shipments of cargoes in very simple code, which could be deciphered by anyone having an elementary knowledge of cryptography. This official was eventually ousted and all the stations closed. Hogg returned to the United States.

In August, at the request of the State Department, Mr. Hogg was again sent to Cuba and resumed activities in detecting clandestine stations. He helped the government establish DF and monitoring stations in connection with plans for hemispheric defense.

An interesting development occurred during Hogg's second assignment. The Cuban police arrested Heinz August Luning and charged him with being a Nazi spy. Hogg reported that the arrest was made prematurely, without notifying the Legal Attache of the American embassy who represented the FBI. Evidence of Luning's activities was scattered through British, American and Cuban censorship who had found secret writing on letters addressed to Sweden and Portugal. After the arrest, a radio transmitter and receiver were found in his room. Hogg interviewed Luning during incarceration and found him able to speak German, Spanish, and English equally well. He had spent some time in South America and carried a Honduran passport with a Cuban visa issued in Portugal.

Luning stated that he had been trained in the German espionage school. In addition to being provided with a forged passport, he was furnished $3,000 in American money and instructions on how to conduct himself while in Cuba. He was told that if it became absolutely necessary to hide, he was to go to the Spanish embassy but only as a last resort.

During his activity in Havana, from April to September, he sent communications regarding shipments and airplanes in secret writing. He corresponded with Carlos Robertson in Chile; they both were expected to set up transmitters to exchange information. Even after he had been arrested, a cable was intercepted from Chile, instructing him to start his transmitter on 1895 kHz and the station in Chile would reply on 11240 kHz. A precise examination of his transmitter revealed that it was incapable of generating RF oscillations. Moreover, because of his lack of technical ability and proper materials it appeared doubtful that he could have ever put it on the air himself. He was subsequently tried by the Havana Urgency Court, convicted, and executed by a firing squad. To my knowledge, he was the only spy other than a group of Nazi saboteurs who landed on Long Island to be executed during the war.

At the request of the U. S. Office of Censorship, RID, aided by Hogg, provided surveillance over communications originating from Cuba Wireless Corporation, a subsidiary of Galban y Lobos Company of Havana. The Cuban government had authorized this company to transmit communications "blind" (one-way) to both Puerto Rico and a New York office. Incidentally, these transmissions were made in the American Morse Code as contrasted with the Continental Code which is used by international agreement. This of course required that we assign intercept officers who could receive American Morse to these circuits. I was informed by the Office of Censorship that our intercepts disclosed indiscreet transmissions relating to movements of ships and cargoes.

SOUTH OF THE RIO GRANDE

In World War I, the high-powered Mexican longwave station at Chapultepec had exchanged considerable clandestine diplomatic traffic with Nauen, Germany (POZ); Yardley in his book The Black Chamber revealed the magnitude of this operation.

As war clouds moved nearer our hemisphere, RID in late 1940 was asked to monitor the Mexican stations since it appeared that coded espionage information was being sent by this commercial channel. In fact, one German spy, licensee of an amateur station, was sending his messages through the Chapultepec station merely by indicating on the messages that they were in a private code. At the time the Mexican government made little attempt to censor international radiotelegraph traffic.

In January of 1941, RID intercepted a clandestine station, with its DF location as Mexico City. This station was heard to communicate at times with the FBI counterespionage station on Long Island. All intercepts were furnished the FBI at their request. It was never revealed what the nature of the operation really was. It could have been a countermeasure station established by the Mexicans, or perhaps the operator recognized the German procedure employed by the Long Island station and its control station AOR.

In June 1941 and March 1942, on request of the Mexican government we sent mobile monitoring units across the border to locate clandestine stations which were suspected to be operating in the northern part of that country. On both trips, all stations which had been reported as suspicious were identified as authorized. Reports of illegal operation were investigated thoroughly and found be the activities of miners and exploring parties operating in the mountains without authority of the Mexican government.

Later we trained two engineers sent by the Mexican government. They went back with RID officer Earnhart and established several DF and monitoring sites.

NAZI SPIES OPERATE IN AFRICA

RID was, as far as could be determined, the first organization to detect the operation of Nazi spy rings in Africa, mostly along the western coast. When we notified our English allies how German agents were reporting the arrival and departure of British naval and merchant ships, our English counterpart, the Radio Security Service, requested establishment of a regular liaison and exchange of information.

German secret agents, as in other countries, were landed by submarine and set up shortwave transmitters in neutral countries and colonies of Africa. They sent to Germany reports of convoy arrivals and departures, and movements of Allied troops, supplies and aircraft. In some instances, the German High Command worked through intermediaries in Lisbon, Madrid, Rome, and Paris so that the control point would appear to be outside the Reich. Actually, of course, the intermediaries or subordinates in these cities were in the pay of the Germany secret service, in constant communication with Berlin by radio, special landline circuits, and couriers.

Radio transmitters had been detected by RID in the Portuguese colonies of Mozambique, Angola, and Guinea. One of the most significant of these African cases revolved about a mysterious control in Lisbon which was in daily communication with Portuguese Guinea and Mozambique.

After RID had perfected the technique of detecting, identifying, and locating clandestine stations which reported to control stations in Germany, a new net working out of Lisbon was discovered. It happened this way: September 3, 1941, W. M. Nicholson, operator at RID Unit SA-6 at South Miami was cruising the radio spectrum. He intercepted the signal of a station sending the call "UU2." Since this call did not conform to those employed by commercial or authorized circuits, and since the procedure was unusual, UU2 became the subject of an RID investigation. Units assigned to the case were instructed to be on the lookout for the answering station. On October 9, a station signing the call CNA was intercepted simultaneously by RID men Frank Toth at Pittsburgh and William Goldberg at Albuquerque. Before this first contact, the control UU2 had been calling almost nightly in hope of contacting its "out" station CNA.

On October 13 another station was intercepted using similar procedures but signing "BX7." Observations and bearings soon proved conclusively that "UU2" and "BX7" were the same control station in Lisbon. On October 20 an intercept of a station signing NPD and in communication with BX7 was reported by Tom Cane, in charge of the RID unit in North Scituate, Rhode Island.

DF bearings by various RID sites soon determined that CNA, which was in communication with UU2, was located in South Africa and NPD, which communicated with the other "out" station BXL, was in Portuguese West Africa.

In working on this traffic to determine whether it was definitely espionage, my men discovered how to break the cipher. These messages were in transposition cipher, but in Portuguese. We got in touch with the FBI which had already been furnished copies of coded texts and gave them the key for decrypting them. Thereupon the FBI and other government agencies evinced keen interest in this circuit. The reason becomes obvious from the following.

The first message to Lisbon that we intercepted reported that the U. S. S. Idaho was at the Port of Durban, South Africa. I made this known to the Director of Naval Communications. He was astonished that we were so proficient in our long-range battle with the Nazi spy system and said he was unaware of such espionage operations going on in Africa.

An English translation of a Portuguese-language code message which was sent to BX7 in Lisbon from NPD on December 4, 1941, is as follows: "Armando reports that the English consul received a long enciphered telegram relative to enforcing a strict vigilance against espionage, officials claimed English still command Cape Verde submarine cable [station], there many men go to Freetown owing to approach of ten convoy ships, large troops, ammunition and tanks. However, informer does not know if they remain at Lagos or Freetown and Bathurst."

Early in 1941 RID monitors intercepted a station using the call MAX. Our bearings showed that MAX was in West Africa. It was later established that this station was actually operated as an espionage outlet from Rio de Oro, in Spanish territory. MAX communicated with Paris. Intercepts of this station were furnished to the Army, Navy, and FBI for months.

Still another clandestine radio was operated by the Germans from a point farther north, near Cabo Judy. This station communicated with Lorient, the German submarine base in France. At times stations in the Canary Islands were active, and other circuits operated between two points in Africa without attempting to contact Europe directly. That is, they fed their traffic to one of the more powerful clandestine radios for relaying to Germany.

There was in operation for a short time a clandestine radio circuit between Spanish Guinea and Madrid, the Madrid control being the same station that was in 24-hour-a-day contact with Berlin on the main European net.

Italian-controlled spies operated a clandestine radio station in Cisneros and communicated daily with Rome until the day our troops landed in Italy. Later monitoring conclusively established that the Cisneros transmitter was no longer in operation, although other stations were still operating from Spanish territory. This circuit originally employed the calls UGI and ULP. Later it went over to the special call system favored by Italian clandestine circuits. The particular call-letter selection made it possible to predict the calls which would be used after only 10 days' observation of the new system. Information regarding this Italian espionage station was furnished regularly to the OSS, State Department, FBI, Army, and Navy.

A station known as AFD, operated by the German Armistice Commission, operated in Casablanca for months until our troops landed in Africa on November 10, 1942. On that day AFD operated practically continuously, sending more five-letter code groups than had been sent in any two days previously. Soon the transmissions ceased as the result of radio intelligence specialists of the OSS going right to the station as soon as our Navy and Army forces opened the way. The last message from this station was intercepted by our station in Rhode Island. RID made the usual multi-agency distribution of intercepts of AFD for months.

CONCLUSION

During its short existence RID located and shut down over 300 unauthorized stations. After the war some of the Division's functions were assigned to other government agencies. RID's contribution to the war effort is an inspiring chapter in the history of electronic intelligence.

RELATED READING

D. Kahn, Hitler's Spies: German Military Intelligence in World War II (New York: Macmillan, 1978).

D. G. Fink, "The Defense Set-up for the Communications Industry," Electronics, November 1940, pp. 16-17.

W. F. Snyder and C. L. Bragaw, "High Frequency Direction Finder Research," in Achievement in Radio: Seventy Years of Radio Science, Technology, Standards, and Measurements at the National Bureau of Standards (Washington, U. S. Government Printing Office, 1986), pp. 317-319.

George E. Sterling, W1AE, was born in 1894. He was an active radio amateur in 1908, long before operator licenses were required. He became a shipboard operator in 1916. Following experience as a radio-intelligence officer in the U. S. Army Signal Corps during World War I, and service on land for RCA, he became a Radio Inspector and examining officer in the Radio Division of the U. S. Department of Commerce. His technical handbook, The Radio Manual, appeared in four editions between 1928 and 1950. He had a distinguished career with the Federal Communications Commission: he served as assistant chief of the Field Section of the Engineering Department, then head of the wartime Radio Intelligence Division, then Chief Engineer, and finally (1948-54) a member of the Commission itself. As Commissioner, he represented the U. S. in several international frequency-allocations conferences.

Commissioner Sterling is a pioneer member of the AWA and the Old Old Timers Club. He was elected a Fellow of the IRE in 1948. He is also an Honorary Life Member of the Radio Club of America and has been elected to the QCWA Hall of Fame.

ELEMENTS OF REFERENCE FOR IDENTIFYING AND DATING WESTERN ELECTRIC ELECTRON TUBES

Attila Balaton
Summit, New Jersey

In this essay a series of elements of reference has been compiled and organized to assist the reader in identifying and assessing the manufacturing date of most Western Electric electron tubes. While essentially based on information available for general-purpose (receiving) tubes, these notes can also be extrapolated and used with transmitting tubes or other electron-tube types manufactured by the Western Electric Company [1]. The paper will successively review the chronology of the different tube types (codes) manufactured, the changes in external tube construction (bulb and base) which took place over time, and finally the evolution of factory markings (code numbers, patent markings, and manufacturing date codes).

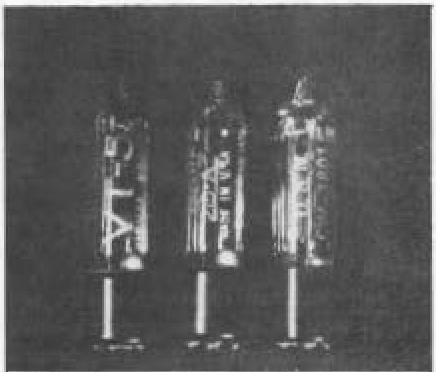
I. TUBE TYPE

I.1. WECo TYPES

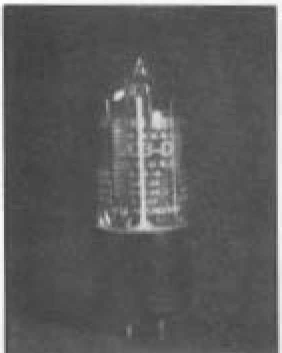
During a period of sixty years (from 1914-15 to the mid-1970s), Bell Telephone Laboratories and the Western Electric Co. issued specifications for more than 500 different electron-tube codes in order to cover an ever-expanding range of applications. Emphasizing this change in scope, tube terminology itself evolved over that period of time: the oldest documents referred first to "telephone repeater elements," then to "repeater bulbs," and finally to "vacuum tubes" (beginning in 1917 for commercial tubes). The latter name was changed to "electron tubes" in 1955. All the following tube types fall under the definition of "electron tubes": general-purpose ("receiving"), transmitting, cathode-ray, magnetron, klystron (reflex oscillator), cold-cathode, spark-gap (radar T-R and lightning protector), Picturephone, photoelectric, traveling-wave and "special" tubes [2].

Alphabetic at the very beginning, then numeric, the individual tube codes were assigned sequentially in the majority of cases, irrespective of tube type. Sometimes codes were reserved for prototypes but never put into production, accounting for several gaps existing in the WECo tube coding sequence. There were five three-digit numeric series specifically used by Western Electric: 100, 200, 300, 400 and 700 [3]. The 100-series was reserved for telephone repeaters (101s, 102s, 104s). The 700-series was for military applications, mainly radar, early in WW II; few of those codes outlived the war [4]. Consequently, the general-purpose tube codes were assigned in the 200-, 300- and 400-series. As a first approximation, the code number itself will help define the first design and manufacturing dates of a given tube. Sometimes it will be helpful in dating

The Navy CW-931 of WW I, equivalent to the Army VT-2.

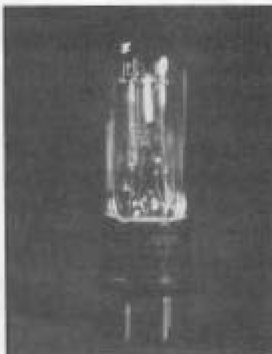


The same tube three ways: an Army VT-5, a civilian 215-A, and a Navy CW-38015.

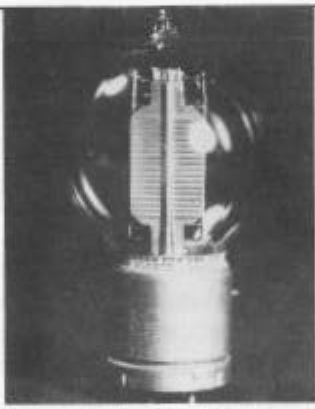


A 203-D triode, with patent dates on the bulb.

The 231-D triode, in "T" bulb; early tipped version.



The 239-A, in "T" bulb but without tip (1928-29).



A 216A with paper-strip license marking.

The 245A tetrode, first WE tube with a UY five-pin base.

tubes, other times not really, as in the case of "long runners" which were manufactured over decades. Table A indicates a few relevant code dates which may be used as guidelines.

TABLE A
BENCHMARK CODE DATES FOR WECo TUBES

YEAR	CODE	DATE CODE RESERVED	DATE MFG. INFO. ISSUED	NOTES
1915	101A	Oct. 1915	Jan. 1916	Triode, First 3-Digit Code
1920	211A	Apr. 1920	Nov. 1921	Transmitting Triode
1925	225A	N/A	May 1925	Transmitting Triode
1930	251A	July 1929	Mar. 1930	Transmitting Triode
1935	305A	May 1934	July 1935	Transmitting Tetrode
1940	359A	Oct. 1939	Jan. 1940	Cold-Cathode Tube
1945	396A	Nov. 1945	June 1948	Twin Triode, Min. 9-Pin
1950	431A	Jan. 1950	May 1950	Reflex Oscillator
1955	444A	Oct. 1955	Apr. 1958	Traveling-Wave Tube
1960	448B	Oct. 1959	Mar. 1960	Tetrode
1965	462A	June 1964	N/A	Traveling-Wave Tube
1976	473A	N/A	Ca. 1976	TWT, Last Code Issued

WECo also manufactured quite a few tubes with a code of the form D-xxxxx or D-xxxxxx. Those were typically assigned by Bell Labs and generally were prototype production indicating the interim improvement or the modification of an existing tube or the introduction of a new model pending wider use. Almost by definition, they were not produced in large quantity. Practically all of them were designed before 1940; they covered a wide range of applications: ionization gauge (D-79510), transmitting triode (D-80039), telephone repeater (D-86326), UHF triode (D-156548), etc. [5]. Bell Labs did not limit this coding scheme to electron tubes, but applied it to other equipment as well. For instance, D-70837 was a condenser microphone [6].

I.2. COMMERCIAL TYPES

In addition, other code schemes have been used by WECo, generally in connection with tubes manufactured for "commercial" (non-AT&T) applications. The most important instance was the production of electron tubes for the U. S. armed forces (Army and Navy). Each corps had its own specifications and coding system until about the end of 1942 when the JAN (Joint Army-Navy) specifications and RMA/EIA (Radio Manufacturers Association, later the Electronic Industries Association) coding scheme for special-purpose tubes was issued. The latter had largely faded from use by about 1950 in favor of a simpler four-digit code. Table B cross-references Army and Navy codes manufactured by WECo with their WECo equivalents (if any).

TABLE B
ARMY AND NAVY CODES MADE BY WECo

ARMY	NAVY	WECo	COMMENTS
-	CW-186	201A	Globular Triode
VT-1	CW-933	203A	Tubular Triode
VT-2	CW-931	205B	Globular Triode
VT-3	-	-	Prototype Only
VT-4	CW-1818	211A	Transmitting Triode
VT-4B	CW-1818A	211D	Transmitting Triode
VT-5	CW-1344	215A	Small Triode
VT-6	CW-1819	212A	Transmitting Triode
VT-6A	CW-1819A	212D	Transmitting Triode
VT-14	CW-1162	-	Transmitting Triode
-	CW-1887	220B	Transmitting Triode
-	CW-2354	225A	Transmitting Triode
-	CW-38015	215A	Small Triode
-	CW-38112	212E	Transmitting Triode
-	CW-38120	220B	Transmitting Triode
VT-52	CW-38142	-	Triode, 45 Special
-	CW-38282	282B	Transmitting Tetrode
-	CW-38412	312A	Transmitting Pentode
VT-106	-	322A	Transmitting Pentode
VT-142	-	39DY1	Doorknob Triode
VT-143	-	331A	Transmitting Triode
VT-166	-	371A	Vacuum Rectifier
VT-191	-	316A	Transmitting Triode
VT-225	-	307A	Transmitting Pentode
VT-230	-	350A	Beam Tetrode
VT-240	-	710A	Transmitting Triode
VT-255	-	705A	Rectifier, WE 378A
VT-269	-	717A	Receiving Pentode
VT-279	-	D-161831	Thyratron

I.3. OVERSEAS TYPES

Quite a few tube codes manufactured by WECo, used for the most part in telephone systems, have also been made overseas by corporations which originally were founded by the Bell System (dating back as early as 1882). In Europe those subsidiaries were placed under a holding company named International Western Electric Company (IWEC), based in Antwerp, Belgium. In 1925, due to pressures from the U. S. Justice Department to divest, AT&T sold IWEC to International Telephone and Telegraph, at that time a startup company (much of what ITT became later can be traced back to the purchase of IWEC). IWEC was then renamed International Standard Electric Company (ISEC). The sale agreement provided for an interchange of technological information and patents and for ISEC to act as selling agent of WECo telephone equipment abroad. Under this provision WECo tube designs were subsequently manufactured overseas. Two of the largest of those one-time overseas subsidiaries were Standard Telephones and Cables Limited (STC) in Great Britain (today still a part of ITT) and Nippon Electric Company (NEC) in Japan. Table C cross-references WECo designs with STC and NEC code numbers [7, 8].

II. TUBE CONSTRUCTION

II.1. TUBE ENVELOPE

Since vacuum-tube manufacturing was originally based on the technology developed for electric lamp production, standard dimensions and specifications for existing glass bulbs were carried over to the new field. The basic shapes available in the early days were globular or "G" (familiarly known as "tennis ball" shape), tubular or "T," and straight-sided tapered or "S" (also known as "pear" shape). Associated with those letters were two digits indicating the maximum bulb diameter in eighths of an inch. For instance, G-19 meant a globe-shaped bulb approximately 2-3/8" in diameter.

The glass bulb associated with all WE telephone repeater tubes from 1914 to 1939 was globular (type G-19). The corresponding codes were in the 100-series. In the 200-series the main "G" types were the 205B/205D (1917-42) and the 216A-217A (1922-44). All the globular shapes were exhausted via a tubulation at the top of the bulb.

The tubular shape was first used by WECo for military and transmitting tubes, like VT-1 (1917), VT-4 and VT-5 (1919-20). By 1925-26, it was also used for receiving tubes (230D, which is identical to the UV-199; 231D, identical to the UX-199). Originally exhausting tubes via a tubulation located at the top of the bulb, WECo switched to a bottom location for the exhaust, probably in 1929.

WECo did not use the straight-sided tapered shape, which was the industry standard during most of the 1920s (with the S-14 bulb used by the ubiquitous UX-201 and UX-201A) until 1929. The instance was the introduction of its first indirectly heated tubes, the 244A triode and 245A tetrode.

In 1931 a new industry standard was introduced with the "ST" shape, a combination of the "S" and "T" forms which WECo also called "dome" shape. It was characterized by an upper section having a smaller diameter than the main section of the bulb. This configuration made a much more rigid positioning of the tube electrodes possible, by giving a second securing point: an upper mica spacer anchored against the glass bulb. It quickly replaced the earlier styles. Among the first WECo tubes to use it was the 274A, a rectifier developed in 1931. The telephone repeater tubes themselves (100-series) were finally converted to the "ST" shape by 1939.

The drive toward VHF-UHF applications brought tube design back to more compact glass bulbs in conjunction with the down-sizing of the internal elements. First there was the so-called "doorknob" shape in 1935-36 with the 316A, which reduced to a "mushroom" size a couple of years later with the 380A and 381A. Then came the tubular shape of the miniature tubes of the 1940s and 1950s, which ultimately supplanted the "ST" shape in almost every low-power application. Interestingly enough, the exhaust tip of the miniature tubes was again located at the top of the bulb.

The last evolution in bulb shape was a short tubular bulb (T-9) with a stiff-lead

TABLE C

WECo DESIGNS MANUFACTURED IN GREAT BRITAIN AND JAPAN

WECo	STC (1)	STC (2)	NEC (1)	NEC (2)
101D/F/G	4101D/F/G	3A/141A	101D/F/G	TB-600A
102D/F/G	4102D/F/G	3A/142A	102D/F/G	TB-601A
104D/F/G	4104D/F/G	3A/144A	104D/F/G	TB-602A
205D	4205D	3B/151A		
211D/E	4211D/E			
215A	4215A			
228A	4228A			
242A/C	4242C	3B/850A		UV-211A
251A	4251A			TC-517A
260A				UX-860
271A				TB-627A
274A/B	4274A/B			
279A	4279A			TC-522A
282B	4282B			
284D	4284D			
300A/B	4300A/B			
304B	4304B			
305D	4305D			
307A	4307A			
310A	4310A	5A/150A	310A	
311A	4311A		311A	
313C				KB-758B
316A	4316A			
319A				4H72
328A	4328A			
329A	4329A			
336A	4336A			
345A	4345A			
349A	4349A			
350A	4350A	5B/250A		UY-807
351A	4351A			
356A				5T33
369A				5H69A
371B				2K71
378A	4378A			
393A				4G93
408A				6028
409A				6R-R8
417A				6R-H2
418A				6B-P16
435A				6R-R21
448A				6B-R22
705A				1K75
715C		P552/10E		
723A/B				2K25
725A			725A	
726B/C			726B/C	
730A			730A	

(1) Direct WECo design.

(2) Listed by the manufacturer as equivalent, not necessarily a WECo design.

stem, like a chubby miniature tube (the same basic shape as the "Compactron" design of the General Electric Co.). WECo first used it with the 418A power tetrode (1948), but the bulb probably will remain best associated with the 435A, 436A, and 437A tubes which arguably represented the ultimate in design of conventional electron tubes.

II.2. TUBE BASE

By 1914 the electron tubes produced by WECo were fitted with a machined brass base having four studs mounted on an insulated insert at the bottom and having on the side a bayonet locking pin which was equidistant from the grid and the plate studs. This was eventually adopted by the tube industry as a standard: the so-called "UV" base.

In late 1917 the machined brass base was replaced with a formed casing of sheet nickel. The contact studs were mounted on an insulated cruciform member and the bottom filled with wax (telephone repeaters) or covered by a phenolic insert (VT-2). The VT-2 also introduced an alternative location for the bayonet locking pin, the pin being now in line with the grid stud, in order to prevent accidental insertion of a receiving tube into a transmitting socket.

In late 1925 the metal base was replaced with a phenolic base which eliminated the problems associated with filling the bottom of the metal base with wax: poor mechanical and heat resistance. At the same time, the contact studs were changed according to what became the new "UX" standard: they were made longer in order to permit contact to be made to the sides of the studs (not only to the tip) and the filament studs were made thicker than the other two in order to assure correct insertion of the tube into a socket. The "wafer" sockets then coming into use no longer had a slotted collar by which the bayonet locking pin could "key in" and position the studs properly [10].

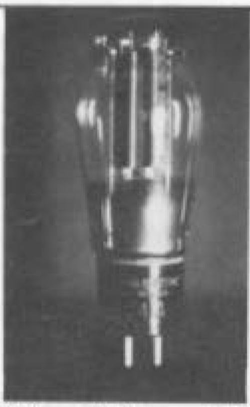
As the need for more pins arose with multi-grid tubes, additional pins were set into the molded base according to tube industry standards at the time: five ("UY") with the 244A and 245A in 1929, six ("UZ") with the 286A RF pentode in 1932. In 1935 the industry got a new eight-pin base, a totally original design by the General Electric Co. intended for the new all-metal tube. The octal base quickly became the standard of choice because of its convenience in the field (ease of insertion of a tube in its socket, thanks to the central spigot providing positive positioning). Apparently WECo first used it in 1938 with the 347A, an AF-RF triode.

Miniature tubes brought an altogether different standard, with no base or pins as such, the stiff lead-in wires serving directly as pins. They fell roughly into the following two categories: WW II period (seven pins, starting with the 6AJ5 and 6AK5 sharp cutoff RF pentodes) and post-WW II era (nine pins, starting with the 396A/2C51 dual triode in 1945).

III. TUBE MARKINGS

III.1. CODE MARKINGS

The very early telephone repeater tubes had their code markings steel-stamped on the brass base. When the latter was changed to sheet-metal (1917), for a while the code markings were only stamped in raised letters in the wax filling at



The 274A rectifier, probably the first WECo tube with an ST bulb.

The 286A pentode, first WECo tube with UZ 6-pin base. Mid-30s Hawthorne sample.

"Doorknob" UHF tubes: 388A, 316A, and 703A. All are marked in red ink.

D-91143, with "S" bulb and hot-branded markings dating from 1929 to the early Thirties.

D-91143, later version with "ST" shape and stamped identification.

the bottom of the base, but by 1918 they were again steel-stamped on the base shell.

Until 1923, all repeater tubes were marked "Property of the American Tel. & Tel. Company" since they were leased to the operating companies with the corresponding repeater equipment. At that time a change of corporate policy took place at AT&T and the tubes began to be sold to the operating companies with the marking: "Western Electric - Made in U. S. A."

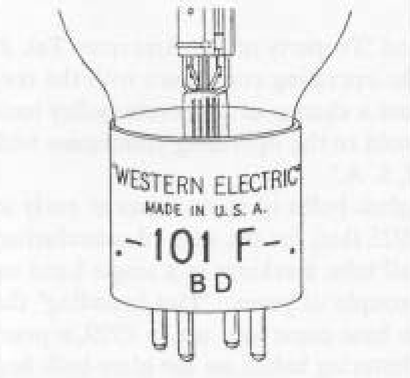
Code markings had been etched on the glass bulbs of some tubes as early as 1920-21 (VT-5/215A) but it was not until 1925 that, for the sake of manufacturing economy, WECo systematically etched all tube markings in a single band on the glass bulbs. The practice lasted for a couple of years. "Hot branding" the code markings into the molded composition base came into use in 1929, a practice followed until the mid-1940s. Enamel lettering baked on the glass bulb had been used by WECo for some transmitting tube markings in the early 1920s but really became widespread with the advent of miniature tubes at the end of WW II. Black (sometimes white) enamel was originally used with transmitting tubes but certainly the most common enamel color was bright yellow, used with all miniature tubes. (Red markings have been used with VHF-UHF power tubes, for instance the 316A and 388A, and the 705A.) Baked enamel was a feature unique to WECo, excellent in terms of legibility and durability.

During the second quarter of 1947, WECo adopted a system of tube markings consistent with the recommendations of JETEC (the Joint Electron Tube Engineering Council). Three types of marking were then in use: base, bulb side, and bulb top. The type was dictated by the manufacturing methods employed, the size of the bulb and base, the quantity manufactured, etc. Base markings and bulb-top markings were hot-branded and rubber-stamped respectively, while the side markings were usually enameled. Until that time, the code markings on Western Electric tubes had been inscribed using a Gothic letter style, which is a fine, straight typeface. The Western Electric logo, designed with the bold, distinctive "Electric Flash" typeface proprietary to WECo, was used infrequently and only on bulb side markings. From 1947 on, the logo was systematically used to print the Western Electric name on the base or the bulb side. All markings on the bulb top, the code numbers themselves and other factory codes continued to be set in Gothic typeface. The base and bulb side markings were done with yellow ink or yellow enamel, the bulb top markings with silver ink.

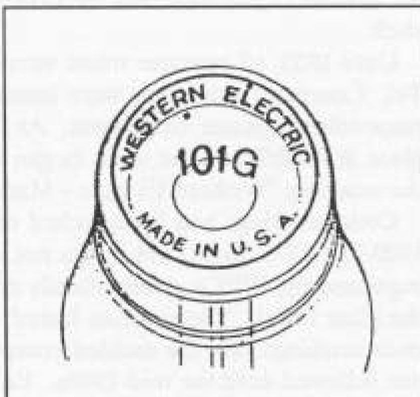
III.2. PATENT MARKINGS

The issuance dates of the patents under which a tube was manufactured were originally steel-stamped on the metal base or, starting in 1925, etched on the glass bulb. In 1928, to conform to a change in patent law, this information was modified from date of issuance to patent number. Especially in the early years, the patent information was often updated. This fact may be used as an additional clue for determining the earliest possible production date.

With the advent of hot-branding the code markings on the composition tube base (1929), the patent markings were removed from the base and printed on a paper strip which was used to seal the tube packing box. Later, those patent numbers, when indicated at all, were simply printed on one of the box flaps (as most manufacturers did).



Typical base marking for date: "BD" implies April 1937.



Typical top marking for date: "RL" designates September 1943.

Molded marking on the base of a 203A/VT-1.

WECo tube boxes from the Twenties through the Sixties.

A telephone repeater tube, military version.

Two items of a style predating the GE Compactron.

III.3. MANUFACTURING CODES

All the early telephone repeater tubes had a serial number etched on the bulb for maintenance records. To distinguish between the vacuum tubes made at the tube shop in Manhattan (first located at 463 West Street, then moved to 350 Hudson Street in 1924) and those made at the Hawthorne plant in the suburbs of Chicago (which began tube manufacturing in late 1919), the letter "H" (later "A") was added to the beginning of the serial numbers of the tubes made at Hawthorne. It is not known precisely when, before the institution of a manufacturing date code in 1936, the serializing of telephone repeaters was discontinued [11].

Originally, a clear distinction was made between vacuum tubes used for telephone repeaters and those used for other purposes ("commercial" or "non-associate" uses). Even with identical electrical characteristics, the latter tubes had a different code number:

TELEPHONE	COMMERCIAL
101B	208A
102A	209A
104A	210A
104D	223A

Then, from late 1922 until mid-1923 when the distinction between telephone and commercial uses was abandoned, commercial tubes used the same code numbers as their telephone counterparts, but with the letter "W" appended, e. g., 101DW, 102DW, 104DW. The "W" append was used for other "non-associate" equipment as well. For instance, the 387 telephone transmitter (microphone) was sold to the outside market as the 387W [12].

Beginning about July 1936, a manufacturing date code was added to the markings on the base of some telephone repeater tubes of the "G" type, namely 101F, 102F, 102D, D-86326, and D-86327 [13]. It was an alphabetical code of two capital letters. The system was as shown in Table D.

TABLE D
SIGNIFICANCE OF DATE LETTERS - FIRST SYSTEM

LETTER	FIRST POSITION	SECOND POSITION
A	Year 1936	January
B	Year 1937	February
C	Year 1938	March
D		April
E		May
H		June
K		July
L		August
M		September
N		October
P		November
S		December

Thus a code "AP" indicated a tube manufactured in November 1936. With the advent of the "ST" type tubes, the code and other markings were sometimes placed on the top end of the bulb. A system of two indices (a radial line or a dot on top of a letter and a dot below another letter) applied to the letters of the name "WESTERN ELECTRIC" was then devised to mark the two letters needed for indicating the manufacturing date code, as shown in Table E.

TABLE E
SIGNIFICANCE OF DATE LETTERS - SECOND SYSTEM

LETTER	INDEX BELOW LETTER: YEAR	INDEX ABOVE LETTER: MONTH
W	1938	January
E	1939	February
S	1940	March
T	1941	April
E	1942	May
R	1943	June
N	1944	July
E	1945	August
L	1946	September
E	1947	October
C	1948	November
T	1949	December

In the second quarter of 1947 the manufacturing date code was changed from alphabetical to numerical. It used a three-digit system. The first digit indicated the year of manufacture according to the following scheme: 6 through 0 indicated 1946 through 1950 respectively, while 1 through 5 indicated 1951 through 1955. The next digits gave the quarter of manufacture, expressed in number of weeks in the calendar year, as follows:

13: weeks 1-13, or January to March inclusive;
26: weeks 14-26, or April to June inclusive;
39: weeks 27-39, or July to September inclusive;
52: weeks 40-52, or October to December inclusive.

Thus the number 652 on a tube indicates that it was made in the period from October to December 1946.

In the first quarter of 1956 the manufacturing date code was modified slightly to use a four-digit system wherein the first two digits indicated the year of manufacture, 56 meaning 1956, etc. The next two digits indicated the quarter of manufacture as seen previously. Accordingly, the number 6526 marked on a tube indicated that it was manufactured in the period from April to June 1965. This latter coding system was used until the discontinuation of electron-tube manufacturing at AT&T. After WW II tube manufacture took place in Allentown, Pennsylvania, and Kansas City, Missouri (beginning in 1958 for the latter). To distinguish the several codes produced simultaneously at both plants, the corresponding output of the KC Works was marked with a small diamond sign. Electron-tube manufacturing ceased at Allentown in 1972 and finally at Kansas City in 1988.

NOTES

1. Unfortunately, they cannot be considered definitive since a few issues have eluded the author and remain unsolved for the moment. Any input from readers having additional information on the subject is most welcome.

2. The major project of producing a complete listing of all electron tubes known to have been manufactured by WECo is being undertaken by B. D. Magers, Senior Production Engineer at the AT&T Kansas City tube plant, now retired. It is anticipated that this work will be published by AWA. It should become a major reference tool for the WE tube enthusiast.

3. Of course, an exception comes to mind: WECo manufactured an ionization gauge tube with the code number 507! RCA made an equivalent tube, the 1949.

4. An article on the 700-series is planned for a forthcoming AWA publication.

5. More information on the D-spec tubes will be given in the October 1990 OTB.

6. This microphone is pictured in Fig. 41 of Bob Paquette's very informative paper "Early Microphone History" in the AWA Review, Vol. 4.

7. The author will attempt to compile and publish a more complete listing of tubes designed by WECo and manufactured overseas, as more information becomes available.

8. Finally, not all tubes bearing typical WECo markings were manufactured by WECo; likewise those labeled "Made *for* Western Electric." A typical instance would be a WECo tube design shared with another manufacturer for enhancing production capacity via second-sourcing. Wartime designs like the 717A or the 723A/B come readily to mind. Another case would be WECo writing specifications for tubes produced for it by other manufacturers. This was probably the case with the VT-52, a medium-power triode also known as the "45 Special," which, while not listed in any WECo tube literature, showed up quite frequently on the surplus market.

9. WECo rarely used octal all-metal tube envelopes, the only examples being the 723A/B klystrons and their successors.

10. From here on the author will follow the accepted practice of calling the studs "pins."

11. The large (and expensive . . .) transmitting tubes continued to be serialized.

12. This double-button carbon microphone is pictured as Fig. 38 of Bob Paquette's paper (*op. cit.*).

13. Consequently, it appears that, until the 1940s, no manufacturing-date coding system was systematically applied to all electron tubes produced by WECo. This is in sharp contrast with RCA, which printed manufacturing code dates as early as 1929. See Bro. Patrick Dowd's monograph "Dating RCA (Cunningham) Composition Base Tubes."

ACKNOWLEDGEMENTS

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BIBLIOGRAPHICAL REFERENCES

AT&T Co., Electron Tube Data Sheets, miscellaneous years.

Bell System Technical Journal, various issues, 1923-75.

Bell Laboratories Record, miscellaneous issues, 1925-75.

Pilkenton, W. H., 100 Years of Excellence: A Chronology of Important Events in the History of the Western Electric Company, Inc., 1869-1969 (New York: Western Electric Co., 1969).

Stokes, J. W., 70 Years of Radio Tubes and Valves (Vestal, NY: The Vestal Press Ltd., 1982).

Tyne, G. F. J., Saga of the Vacuum Tube (Indianapolis: Howard W. Sams Co., Inc., 1977).

Attila R. Balaton

A lifelong enthusiast for high-quality sound reproduction, Attila R. Balaton acquired an early appreciation for vacuum tubes by scratch-building audio amplifiers. Since his academic background (U. of Paris, UCLA) and work experience are in a different field of endeavor, he considers himself a dedicated amateur. An interest in researching, documenting, and preserving the early era of electrical sound reproduction (1920-1950) brought him into contact with several members of AWA who encouraged him to join. His particular area of interest is the research done at Bell Laboratories on high-quality sound reproduction and the resulting products manufactured by WE during those 30 years. He welcomes correspondence from any AWA member who can help him locate or document tubes or other artifacts for future publications on the subject.

SAN FRANCISCO'S NETWORK BROADCAST CENTERS OF THE 1930s

John F. Schneider
Seattle, Washington

INTRODUCTION

The period of the 1930s and '40s has been appropriately called "Radio's Golden Age." During these years, the nation was entertained and informed by a host of live coast-to-coast network broadcasts. Radio historians have correctly identified the importance of New York, Hollywood and Chicago as network production centers during these years. However, little has been said about the role played by San Francisco.

The decade from 1927 to 1937 can easily be termed San Francisco radio's "Golden Decade." It was during that ten-year span that the city was a major origination point for nationwide network broadcasts, and that both NBC and CBS maintained production centers there.

THE NBC ORANGE NETWORK

Immediately after the National Broadcasting Company's first broadcast on the East Coast, November 15, 1926, the network began seeking routes of expansion. On January 1, less than two months later, a second NBC network was instituted, again serving only the eastern two-thirds of the nation. To distinguish between the two separate telephone-line networks, AT&T technicians used red designators at their jack panels for the original network's connections, and blue designators for the newcomer. The names of the two networks were casually derived from these practices, and the two networks became the NBC Red Network (the WEAF group) and the NBC Blue Network (the WJZ group).

In the beginning, NBC was "National" in name only, as its programs reached only as far west as Denver. In its first years, the company was unable to set up a coast-to-coast hookup. AT&T had not yet installed broadcast-quality telephone lines across the Rocky Mountains [1]. To alleviate this problem, the NBC Board of Directors voted on December 3, 1926, to establish a third NBC network: the Pacific Coast "Orange Network" [2]. They assembled a full duplicate of the New York program staff in San Francisco, and the Orange Network began originating programs for seven Pacific Coast stations: KPO and KGO in the Bay Area, KFI Los Angeles, KFOA San Diego, KGW Portland, KOMO Seattle, and KHQ Spokane. The seven stations were connected by 1709 miles of program lines [3].

Broadcast of "Carefree Carnival" from the stage of the Marines' Memorial Theater in San Francisco. This photo, taken in 1936, shows Meredith Willson, right center, conducting the NBC orchestra.

All photos: Schneider collection

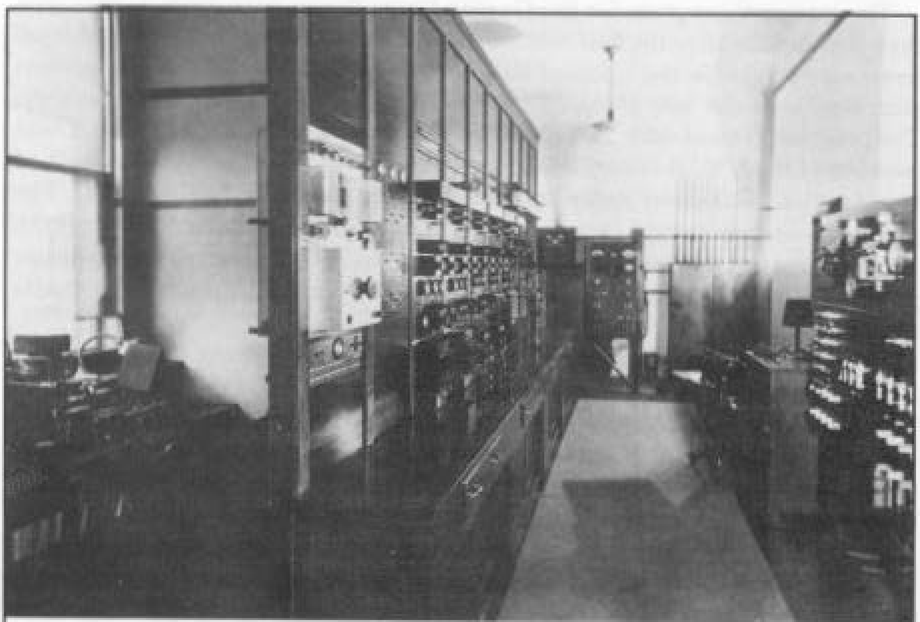
The inaugural program for the Orange Network was held April 5, 1927, less than five months after the first NBC broadcast in New York. It originated from temporary studios in the Colonial Ballroom of the St. Francis Hotel, as permanent studios in the new Hunter-Dolin Building were not ready for occupancy. The program opened with an address by Henry M. Robinson, the Pacific Coast member of the NBC Advisory Board and president of the First National Bank of Los Angeles. Robinson spoke from the studios of KFI in Los Angeles. The program was then turned over to San Francisco for the broadcasts of music by Alfred Hertz and the San Francisco Symphony, and by Max Dolin, the newly-appointed West Coast music director, conducting the National Broadcasting Opera Company.

On April 11, the network began regular broadcasting with the program "Eight Neapolitan Nights," sponsored by the Shell Oil Company. The initial network schedule was 8 to 9 PM Monday and Saturday, and 9 to 10 PM Tuesday through Friday, giving the network a total of six hours of programs weekly [4]. (At first the networks operated only in the evenings because circuits could not be spared from the standard telephone service during the busy daylight hours [5].)

The Orange Network recreated the programs heard in the East on the Red Network. At the conclusion of a program in New York, all the program continuity, including the scripts and musical scores, would be shipped to San Francisco by Railway Express, where it would be rehearsed for performance exactly a week later. Thus, the San Francisco cast was producing such well known early network shows as "The RCA Hour," "The Wrigley Program," "The Standard Symphony Hour," "The Eveready Light Opera Program," and "The Firestone Hour." At the conclusion of each program the announcer would say, "This program came to you from the San Francisco studios of the Pacific Coast Network of the National Broadcasting Company." This would be followed by the traditional NBC chimes. The chimes were a part of all NBC programs from the very beginning; however, they were considerably longer and more involved than the later three-note chime. Because they were so long and clumsy, they were shortened to the better known G-E-C progression. It is said that the notes G-E-C stood for the "General Electric Company," a melodic tribute to one of the network's major parent corporations. The original NBC chimes were struck by hand, but were replaced in the mid-Thirties with electronically-produced, perfect-pitch chimes [1].

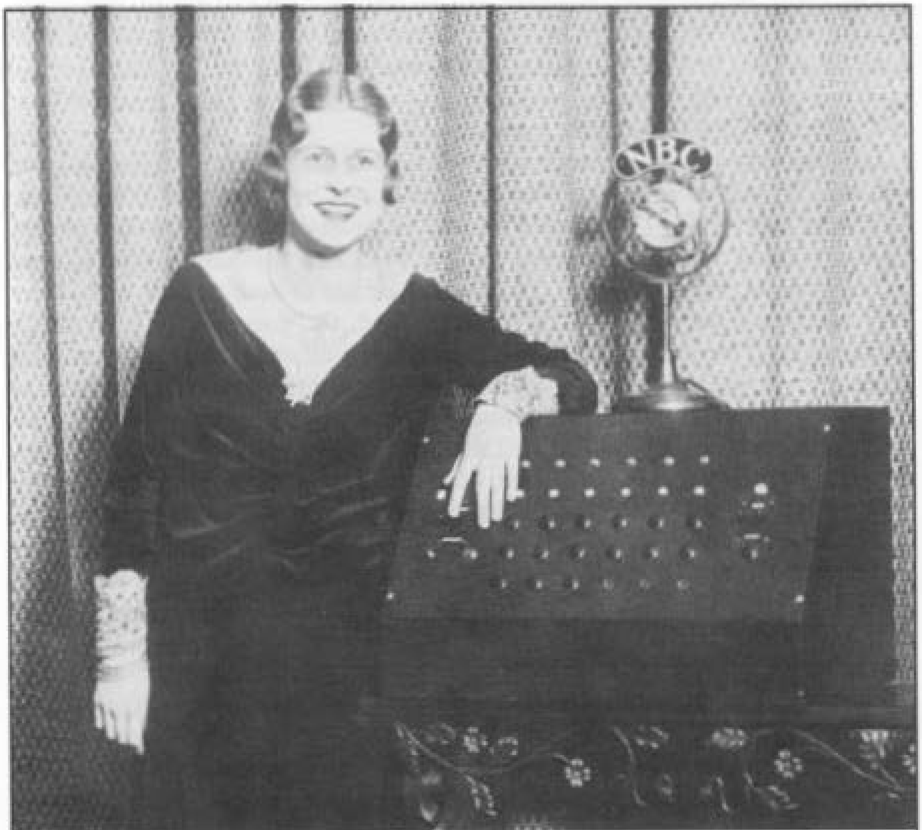
Shortly after the Orange Network's inaugural broadcast, the staff moved into its permanent headquarters in the Hunter-Dolin Building at 111 Sutter Street. The NBC studios occupied the entire 22nd floor, while the network offices were located on the second floor. The studio complex included three completely equipped studios and an elaborate new pipe organ. It was in these studios that most of San Francisco's "Golden Decade" programs would originate. The entire NBC complex was decorated in a Spanish motif; one of its more unusual features was a glass-enclosed mezzanine, decorated to resemble a Spanish patio. It was designed so that a small audience could watch the programs while they were being broadcast. Some of the heaviest users of the booth were the sponsors of the programs, and this experience sparked the establishment of sponsors' booths in network studios across the nation.

To staff its new network in San Francisco, NBC drew primarily from the ex-



Part of the master control room at NBC's Pacific Coast headquarters at 111 Sutter St., San Francisco. The amplifiers on the panels at left fed the telephone lines to the affiliated stations.

An NBC remote-broadcast truck, as seen in 1931 in front of the California Palace of the Legion of Honor.



An NBC employee shows off one of the "announcer's delight" control panels, which connected the various microphones in the studio to the program circuits. Operation of this panel was the responsibility of the announcers, not the engineers, which occasionally led to embarrassing switching errors.

isting area radio stations. KGO and KPO (now KNBR), the NBC affiliates, were hardest hit, and as the network schedule was expanded this process continued. One of the most popular KPO personalities to make the move was Hugh Barrett Dobbs, who moved his "Ship of Joy" program to the network, where it became the "Shell Ship of Joy," sponsored by the oil company of the same name. Another person to make the move was Proctor A. "Buddy" Sugg, who came to NBC from KPO as a technician and gradually moved up the ladder until he became the nationwide executive vice president of NBC.

During the first few years of operation, program announcements were made by actors, musicians, or generally whoever was available. However, as the staff continued to grow, the first full-time staff announcer was hired. He was also borrowed from a local station: Bill Andrews moved from KLX in Oakland to NBC in 1928. Other announcers followed: Jack Keough came from KPO; Jennings Pierce was recruited from KGO; Cecil Underwood was imported from affiliate KHQ in Spokane. Many others were gradually added until there were 17 at the height of the operation. Andrews became chief announcer in 1933 [6].

The entire NBC-Pacific operation was headed by Don E. Gilman, vice president in charge of the Western Division. Gilman had been recruited from a local advertising firm in 1927 to manage the operation. Prior to that time, he had been one of the best known advertising men in the West, and had been president of the Pacific Advertising Clubs Association [7].

Initially, although the network provided several hours of programming to its affiliates, it had little impact over the day-to-day operations of the stations. KGO was operated by the General Electric Company, and KPO by Hale Brothers Department Store together with the San Francisco Chronicle. This changed in 1932, when NBC leased the licenses and facilities of both stations (they were later purchased outright). When this happened, the program staffs of KGO, KPO and NBC were combined into one collective staff of over 250 persons. This included complete orchestras, vocalists and other musicians (there were five pipe organists alone), and a complete dramatic stock company. The entire operation was consolidated under one roof at 111 Sutter Street. It was there that all programming originated for the network, which then averaged about fifteen hours a week, as well as local programs for KGO and KPO. As a result, these stations lost their independent identities, except for their separate transmitter facilities [1]. (KGO operated at 7500 watts from a General Electric factory in East Oakland. KPO transmitted from the roof of the Hale Brothers Department Store with 5 000 watts until 1933, when a new 50,000 watt facility was constructed on the bay shore at Belmont.)

The old KPO studio at the department store continued to be used for just one NBC program, "The Woman's Magazine of the Air," with host Jolly Ben Walker. This was a morning home-economics show popular in the West for many years. Reportedly, the first bona fide singing commercial - that is, one sung for the sole purpose of praising a product - was heard on this program. The commercial was for Caswell's National Crest Coffee, and, according to Bill Andrews, "went something like this":

> Coffees and coffees have invaded the West,
> But of all of the brands, you'll find Caswell's the best.
> For good taste and flavor,
> You'll find it in favor.
> If you know your coffees,
> Buy National Crest [1].

Some of the other programs that originated from 111 Sutter Street during these years were "Don Amaizo, the Golden Violinist," who played for the American Maize Company (the musician who performed for West Coast audiences was Music Director Max Dolin); "Memory Lane"; "Rudy Seiger's Shell Symphony," broadcast by remote from the Fairmont Hotel; "Dr. Lawrence Cross"; and the "Bridge to Dreamland," originated by Paul Carson and consisting of organ music by Carson intermixed with poetry written by his wife.

Throughout all of these programs, even though the performers went unseen by their radio audiences, NBC required formal dress. This meant that actors and announcers wore black ties, actresses wore formal gowns, and musicians wore uniform smocks, with the conductor in tie and tails. This was done for appearance, in the event that the sponsor or some other important person should drop in unannounced.

Until September of 1928, there was still no such thing as a weekly "coast-to-coast" network program. Even then, the connection between Denver and Salt Lake City was a temporary one made by placing a long distance telephone call. For a few months, eleven sponsors reached the Pacific Coast with their programs using this method. AT&T finally completed the last link in the broadcast-quality telephone network in December of that year. The first program to use the new service was "The General Motors Party" on Christmas Eve, 1928. Regular programming began shortly thereafter, and western listeners could now enjoy the original eastern productions for the first time. NBC now boasted a nationwide network of 58 stations, with the potential to reach 82.7% of all U.S. receivers [8].

With the inauguration of the new transcontinental service, the process of duplicating the programs of the eastern networks in San Francisco was discontinued. Because only one circuit had been installed, however, the Red and Blue networks could not be fed simultaneously. Instead, a selection of the best programs from both networks was fed to San Francisco, where they were relayed to the western affiliate stations. Thus, the Orange Network continued to exist, although in name only [1].

Even though the duplication of programs was no longer needed, the Western Division staff was not dissolved. It continued to produce additional programs for western consumption only, which were used to augment the eastern schedule. In addition, the transcontinental line would occasionally be reversed, and programs produced in San Francisco would for the first time be fed eastward to the rest of the nation. The first nationwide broadcast from the West Coast had been the Rose Bowl Game from Pasadena on New Year's Day, 1927, with Graham McNamee at the microphone [5]. However, this had been accomplished on a temporary hookup over normal phone lines. The first regular coast-to-coast broadcast from the West over high-quality lines took place in April of 1930, with the broadcast of the "Del Monte Program" sponsored by the California Packing Company. Other programs quickly followed. Soon the San Francisco staff was bigger than ever, simultaneously producing programs for local broadcast over KGO and KPO, for the western hookup, and for nationwide consumption. All of these production activities were further complicated by the time difference between the East and West Coasts. This meant that a program for broadcast in the East at 7 PM would have to be performed in San Francisco at four, and then repeated three hours later for western audiences. Thus, it was not uncommon to have all three San Francisco studios in use at once: one producing a program for the East Coast, another for the West Coast, while a third was producing for one of the local stations.

Several programs produced in San Francisco within the next few years quickly gained nationwide popularity. Programs such as "Death Valley Days," "The Demi-Tasse Revue," and Sam Dickson's "Hawthorne House" quickly gained nationwide popularity. Dickson was one of San Francisco's best-known radio writers. He got his start there in the Twenties at KYA, writing shows that featured the station manager and the switchboard operator as principal characters. In 1929, Dickson conducted a survey for the Commonwealth Club about radio advertising. Broadcast advertising had not yet come into its own, and there were many who voiced objections to radio being put to such a use. Dickson's survey was revolutionary, in that it discovered 90% of the city's radio listeners did not object to commercials, providing they were in good taste; virtually all of them actually said they patronized the few advertisers that were then on the air. The results of Dickson's survey were indeed revolutionary, but they also prompted a revolution he didn't expect - he was blacklisted by every station in town! [9]

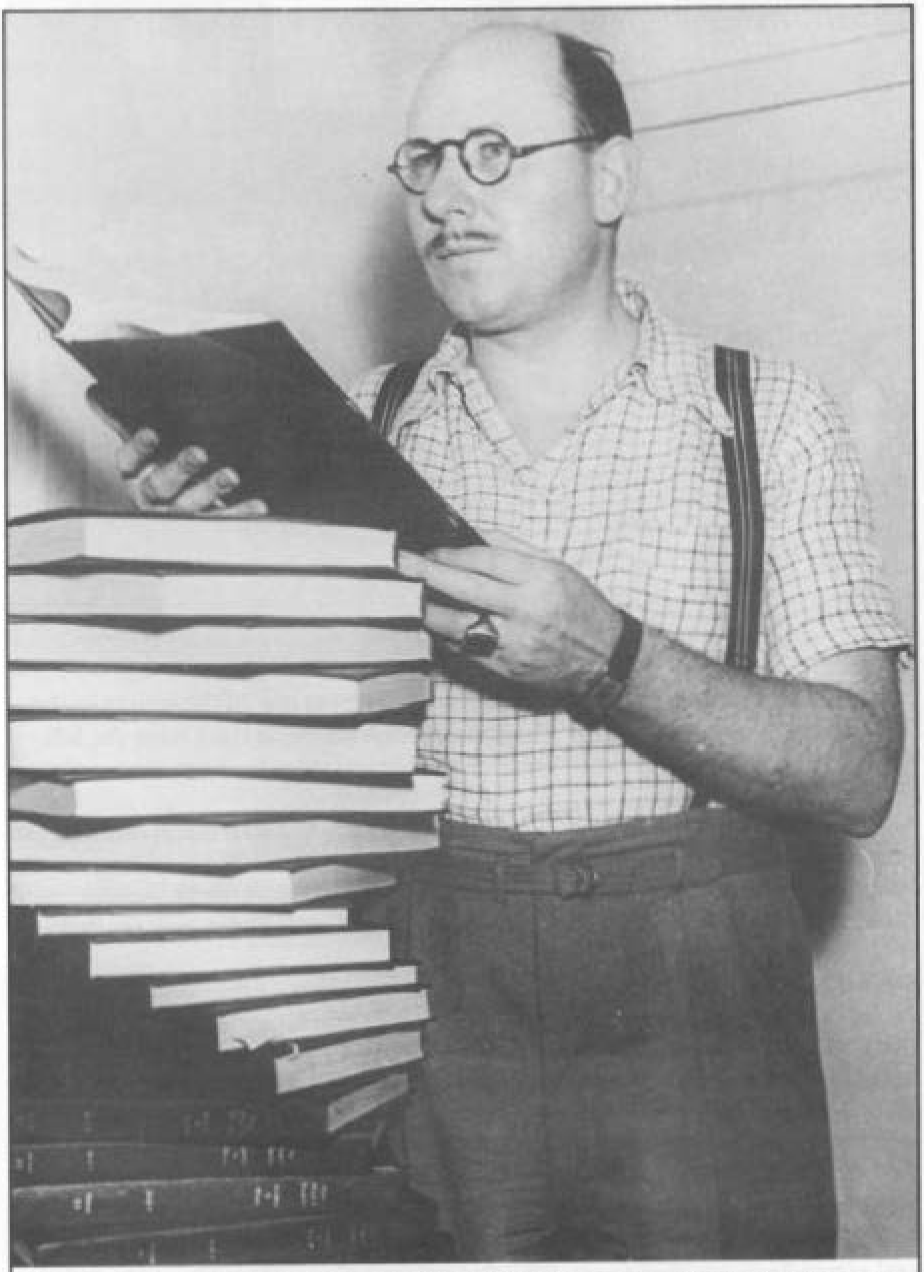
Sam Dickson fought the blacklisting as best he could. He was still doing some writing for KYA, and managed to do some for NBC under an assumed name. By the time NBC discovered his true identity, however, his work had become admired to the point where he was allowed to remain as a staff writer. He wrote scripts for many programs in the ensuing years, including two popular series, "Hawthorne House" and "Winning of the West," as well as police stories and biblical stories for children. He continued with NBC as one of its most prominent writers up into the Sixties, and later was the author of "The California Story," a series heard on KNBC (formerly KPO, now KNBR) for a quarter century [9].

Several other San Francisco programs were nationally known. One was "Carefree Carnival," sponsored by the Signal Oil Company. This was a program of western music and skits broadcast from the stage of the Marines' Memorial Theater beginning in 1934. It was hosted by homespun Charlie Marshall and featured Meredith Willson's Orchestra. The most famous program ever to originate in San Francisco, however, was "One Man's Family." This program was a national favorite on radio and television for 27 years, and was always among the ten most popular programs in the nation. Its author, Carleton E. Morse, was the biggest figure in San Francisco radio at the time.

Morse was a newspaperman who made the transition to radio with NBC in 1929. He authored numerous successful radio productions, including "House of Myths," "The City of the Dead," "Dead Men Prowl," "Chinatown Squad," and "Barbary Coast Nights," before developing "One Man's Family." It told the story of the Barbour family, an affluent, moral family residing in the Sea Cliff district of San Francisco. This series did not fit into any previously used program formula - it was unlike anything that had been done on radio up to that time. It simply told the story of everyday life in a model family. Morse hoped it would become popular because the public would identify closely with its characters.

The program made its debut on Friday, April 29, 1932. It was carried from 9:30 to 10:00 PM on just three stations, in San Francisco, Los Angeles and Seattle. However, after the first few episodes, the other West Coast stations requested that the program be opened to the entire network [10].

Western listeners responded to the program almost immediately, and their response was overwhelming. "One Man's Family" quickly became one of the most listened-to programs on the Coast. However, the story concept was new, and companies were reluctant to sponsor it. After almost a year as an unsponsored feature, an announcement was made at the end of an episode that NBC was considering dropping the program, and that audience response was being solicited. The thousands of letters that swamped the mail room overwhelmed everyone, especially Morse. In a final, desperate attempt to woo a sponsor, the Sales Manager hired a suite of rooms in one of San Francisco's posh hotels and scattered the many letters over the floors, furniture, and every other horizontal surface. After wining and dining officials of the Wesson Oil Company in the hotel dining room, he took them up to the suite, where he showed them the scene and invited



Carlton Morse, author of the popular "One Man's Family" series, is shown reviewing some of his scripts, bound into the program's famous "books."

them to read just one letter. Needless to say, they bought the series; Wesson Oil and Snowdrift became sponsors of "One Man's Family" January 18, 1933 [10].

Soon after, on May 17 of that year, the program became one of the first San Francisco programs to be piped through the transcontinental line to the East,

The cast of "One Man's Family" is shown performing one of the scripts in the NBC studios at 111 Sutter St. Announcer Bill Andrews is third from the left.

where it was heard nationwide for the first time. Wesson Oil sponsored the western production, while the version heard in the East was sustaining, or unsponsored. Separate scripts had to be utilized for nearly eight months, until eastern audiences could catch up with the story line and the two productions could be consolidated [10].

NBC took two major steps in 1936 that had a profound effect on Pacific Coast radio. The first was the opening of a second Pacific Coast network. Now, for the first time, the entire complement of programs from both NBC networks could be heard on a nationwide basis. The original NBC "Orange Network," with the exception of KGO, became the Pacific Coast Red Network. KGO, along with KECA Los Angeles, KFSD San Diego, KEX Portland, KJR Seattle, and KGA Spokane formed the new Western Blue Network [11]. The latter three stations had been a part of the "Gold Network" from 1931 to 1933, after the demise of the Seattle-based American Broadcasting Company, the first of several networks to use that name. The Gold Network was discontinued by NBC in 1933 to save line costs [12]. The West Coast Blue Network began with the broadcast of the Rose Bowl Game from Pasadena on New Year's Day, 1936 [13].

The second major event of 1936 - the one that ultimately proved to be fatal for San Francisco's position as a broadcast center - was the breaking of ground for NBC's new Hollywood studios. This was in response to the American public's increasing desire for West Coast programs. The success of "One Man's Family" and other early Coast offerings played a part in this process. But more important was the public's desire to hear their favorite Hollywood movie stars on the radio. Rudy Vallee apparently started the trend in the early Thirties. While in Hollywood for the making of a motion picture, he broadcast his weekly program from California and introduced his audience to film-star guests [6]. This trend advanced rapidly, and there were no fewer than 20 network programs released from Hollywood over NBC and CBS during the 1934-35 season.

In the first years of the network, it had been necessary for Hollywood stars to travel to San Francisco to make a broadcast, a requirement that severely limited the frequency of their appearance. This had been necessary because AT&T's broadcast lines fed from San Francisco to Los Angeles, and not the other way around. Programs were fed nationwide from city to city on a serial hookup, and Los Angeles was the end of the line. In order for programs to be fed nationally from Los Angeles, they would have to be fed eastward by a separate circuit to Chicago, where they could connect into the network. When Eddie Cantor moved his "Chase and Sanborn Program" to Hollywood in 1932, this aspect added $2,100 per week in line charges to the program's budget [14].

The limitations of the AT&T network began to be overcome in 1936, under pressure of the network's desire to satisfy the public's taste for Hollywood programming. The new circuit that was constructed to bring the Blue Network to the Coast in 1936 terminated in Los Angeles instead of San Francisco. Further, AT&T had incorporated a new system called the "quick reversible" circuit. Under this arrangement, the operation of a single key would reverse the direction of every amplifier in the line between Los Angeles and Chicago, so that the same line that formerly fed westward could now move programs from west to east. The circuit could be completely reversed in less than 15 seconds, well within the time of a station break [15]. Thus in 1936 it became economical to produce national programs in Hollywood on a wide scale for the first time. Big Hollywood names like Al Jolson, Bob Hope and Clark Gable were regularly heard on NBC after that year.

The new NBC Hollywood studios officially opened for business October 17, 1938. Sprawling over a 4-1/2 acre tract at Hollywood and Vine, the $2 million facility became the new Western Division headquarters for the network. The West Coast executive offices that had been divided between San Francisco and Los Angeles were consolidated in a new three-story executive building. There were eight studios, including four auditoriums that seated 350 persons each, the largest ever constructed for radio [16].

The opening of the Hollywood studios and improvements to the AT&T leased-line system marked the beginning of a gradual exodus that, over a five-year period, saw virtually all of San Francisco's network programming move to Hollywood. By 1942, only a skeleton crew remained to program the local stations. One of the first programs to leave was San Francisco's beloved "One Man's Family." Production of this program was transferred to Hollywood in August of 1937, even before the new studios had been completely finished [10].

For a while, NBC intended to operate equal personnel and artist staffs in both cities [17]. To that end, NBC began to draw up plans for an elaborate new studio building in San Francisco to replace the outmoded facility at 111 Sutter Street and match the opulence of the new Hollywood facility. This was NBC's "Radio City," which drew national acclaim for both its architectural and broad-

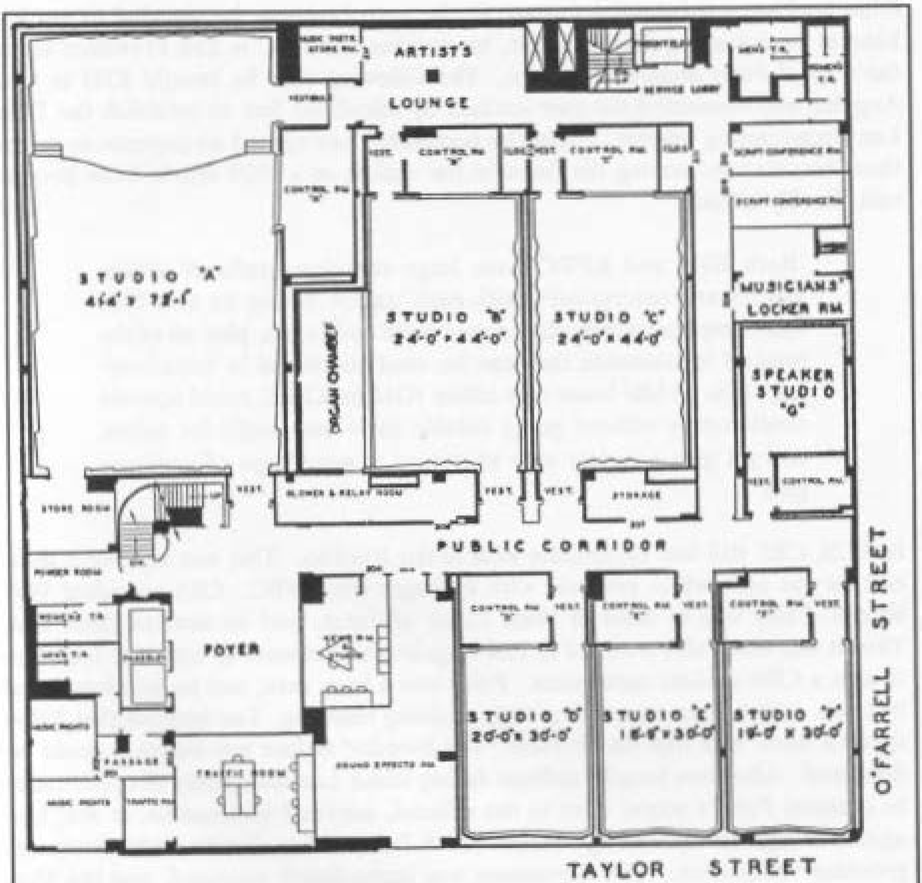
NBC's "Radio City" at Taylor and O'Farrell Streets, San Francisco, as it appeared in 1941.

cast features. And it was built by mistake.

Plans were drawn up and bids taken in 1940 for the construction of an ultra-modern four-story studio complex at Taylor and O'Farrell Streets. Meanwhile, NBC apparently changed its mind and decided to move all the remaining operations to Hollywood. According to one story, the ground breaking was set to begin when the West Coast vice president received a telegram from New York. It said a decision had been made to phase out the San Francisco operation, and that the new building must not be built. But, it was too late; the event, once set into motion, could not be reversed. The vice president himself officiated at the ground breaking ceremony that day, the telegram in his pocket.

The million-dollar facility was formally dedicated April 26, 1942 [18]. It was an impressive edifice, four stories of pink, windowless walls with layers of glass brick outlining each floor. Over the marquee, at the main entrance to the building, was a three-story mosaic mural designed by C. J. Fitzgerald which depicted different facets of the radio industry. Inside, facilities included a 41-by-72 foot main studio, two 24-by-44 secondary studios, and four smaller studios. In addition, a parking garage occupied practically the entire first floor. One of the smaller studios, Studio G, was equipped with a false fireplace, fur rugs and comfortable furniture. It was reserved for VIP guests exclusively; Harry Truman, General Sarnoff and H. V. Kaltenborn were just a few of those who eventually used it. Another feature of NBC's radio palace was a roof garden where Sam Dickson, Dave Drummond, James Day and other staff writers would produce scripts in their swimsuits and work on their suntans at the same time [19].

The building was a magnificent tribute to the state of the art. It was also San



Second Floor Plan - NBC Building - San Francisco

Francisco's last great fling as a radio center, for less than a year after its completion the southward exodus had ended, and most of the facility stood unused except for an occasional network sustaining feature. In the ensuing years much of the building was leased as office space, and the entire radio operation consisted of a disc jockey playing records in a third floor booth. KGO was moved to Golden Gate Avenue in the early 1950s, and KPO, by then known as KNBR, moved out in 1967. That was the year the building was sold to Kaiser Broadcasting Company, and became the new home of KBHK Television. At last, it finally began to see extensive usage for the purpose for which it was built [20].

THE DON LEE-COLUMBIA SYSTEM

During the Thirties, 111 Sutter Street was not the only network broadcast address. The other was 1000 Van Ness Avenue, the Don Lee Cadillac Building, headquarters for KFRC and the Don Lee-Columbia Network. It was there that another radio legend was born.

Don Lee was a prominent Los Angeles automobile dealer, who had owned all the Cadillac and LaSalle dealerships in the State of California for over 20 years.

After making a substantial fortune in the auto business, he decided to try his hand at broadcasting [21]. In 1926, he purchased KFRC in San Francisco from the City of Paris department store. The following year he bought KHJ in Los Angeles and connected the two stations by telephone line to establish the Don Lee Broadcasting System. From the beginning, Lee spared no expense to make these two stations among the finest in the nation, as a 1929 article from Broadcast Weekly attests:

> "Both KHJ and KFRC have large complete staffs of artists, singers and entertainers, with each station having its own Don Lee Symphony Orchestra, dance band and organ, plus all of the musical instruments that can be used successful in broadcasting. It is no idle boast that either KHJ or KFRC could operate continuously without going outside their own staffs for talent, and yet give a variety with an appeal to every type of audience [22]."

In 1929, CBS still had no affiliate west of the Rockies. This was making it difficult for the network to compete with its larger rival, NBC. CBS president William S. Paley was in need of West Coast affiliates, and he needed them fast. Thus it was that Paley traveled to Los Angeles that summer to convince Don Lee to sign a CBS affiliate agreement. Paley was a busy man, and he was frustrated by Lee's casual, time-consuming ways of doing business. Lee insisted that Paley spend a week with him on his yacht "The Invader" before any business could be discussed. After two lengthy sailings during which Lee had plenty of opportunity to evaluate Paley's moral fiber in the relaxed, informal atmosphere at sea, Lee agreed to sign an affiliate agreement which Paley was to dictate without any negotiation whatsoever. The agreement was immediately executed, and the Don Lee stations became the vanguard of the CBS West Coast invasion on July 16, 1929 [23].

The new chain was called the Don Lee-Columbia Network. Two more stations, KGB San Diego and KDB Santa Barbara, were purchased by Don Lee and became a part of the network. Also, Lee had been feeding programs to the McClatchy Newspaper station KMJ in Fresno since 1928, and that station became a CBS affiliate, along with the other McClatchy stations (KFBK Sacramento, KWG Stockton, and KERN Bakersfield). Additionally, four Pacific Northwest stations called the "Columbia Northwest Unit" were added (KOIN Portland, KOL Seattle, KVI Tacoma, and KFPY Spokane) [24].

KFRC and KHJ originated numerous programs for the West Coast network. CBS programs were heard in the early dinner hours, and the Don Lee programs were fed after 8:00 when the eastern programs ceased [25]. Additionally, several of the San Francisco and Los Angeles programs were broadcast nationally by CBS. Many of the most popular KFRC programs became network offerings in this way. Some of the most famous Don Lee-Columbia programs that originated from San Francisco were "Chiffon Jazz," "Salon Moderne" with Bea Benederet, and the "Happy-Go-Lucky Hour" with brothers Al and Cal Pearce, which debuted in 1929. The latter program was heard nationally on CBS until 1933 when it moved to NBC and became "Al Pearce and His Gang," a radio staple through

The cast and musicians of the "Blue Monday Jamboree" posed for this portrait on the mezzanine stairway of the KFRC studios.

the Forties. Another early program to originate in San Francisco was "Blue Monday Jamboree," a two-hour radio vaudeville extravaganza that became a West Coast sensation. The program was first created in 1927 by Harrison Holliway, KFRC station manager, and was heard nationally on CBS by the end of 1930 [26]. It was eventually moved to Los Angeles and became "The Shell Chateau" with Al Jolson [27].

Perhaps one of the most notable aspects of KFRC and the Don Lee System during this period is the large number of people they graduated to national stardom. Meredith Willson was an unknown flutist when Lee hired him in 1929 to be KFRC's Music Director. Jack Benny's announcer Don Wilson began his radio career at KFRC as a member of the "Piggly-Wiggly Trio" before becoming a member of the announcing staff. Ralph Edwards and Art Van Horn were also announcers; so was Mark Goodson, who had a knack for quiz shows. He had several on the Don Lee Network before he left for New York and teamed up with Bill Todman. Others first heard on the Don Lee System from KFRC were Art Linkletter, Harold Peary, Morey Amsterdam, Merv Griffin and John Nesbitt [28].

Don Lee died suddenly of heart failure on August 30, 1934, at the age of 53, and Lee's son Tommy became president of the network [29]. This presaged a series of events which completely restructured network broadcasting on the West Coast over the next three years. CBS was apparently becoming increasingly dissatisfied with the structure of its western network. The affiliation between CBS and Don Lee, which had been a convenient mechanism for Paley to add affiliates quickly in 1929, was becoming a source of friction as CBS sought more and more control over its affiliates and programming. Apparently this friction even preceded Lee's death [29]. In any event, it came to a head March 19, 1936, when

Harrison Holliway, KFRC manager and chief announcer, emcees a broadcast of the "Blue Monday Jamboree" on the Don Lee - Columbia Network.

CBS consummated its purchase of KNX in Los Angeles for $1.25 million. This was the highest price ever paid for a radio station to that time. The acquisition of KNX gave CBS a 50-kW clear-channel network-owned facility in an increasingly important market. As mentioned previously, Hollywood-originated programs were becoming highly sought after by the radio public, and KNX would become the springboard for a major CBS West Coast program origination effort [30]. The network's new studios, Columbia Square in Hollywood, were officially dedicated April 30, 1938 [31].

Of course, the acquisition of KNX by CBS destroyed any remaining relationship with the Don Lee network. The purchase meant that KNX would replace

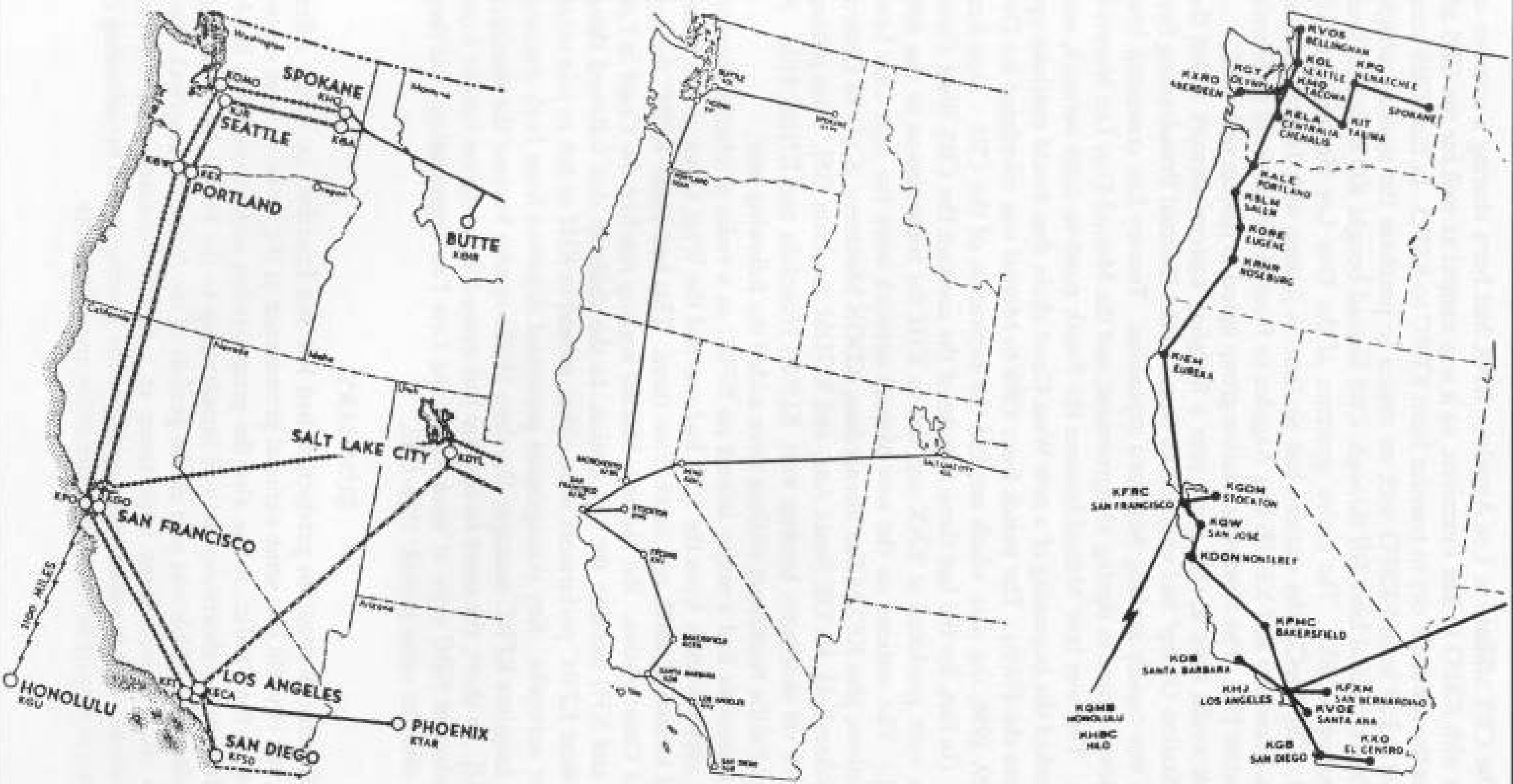
KHJ as the CBS affiliate in Los Angeles. KNX had been sharing a number of programs with KSFO in San Francisco, so it was natural as well for the CBS affiliation in the northern city to transfer from KFRC to KSFO. In fact, CBS soon announced it had leased KSFO with an option to purchase the station outright [32]. (When that deal later fell through, CBS instead bought KQW in San Jose, which became KCBS.) The entire structure of the Don Lee Network quickly collapsed. The McClatchy stations lost no time in joining with Hearst stations KYA San Francisco and KEHE Los Angeles to form the short-lived California Radio System [33]. The Northwest station group opted to remain with CBS.

As luck would have it, that same year a fledgling eastern network called the "Quality Station Group" had changed its name to the "Mutual Broadcasting System" and was rapidly seeking westward expansion. Tommy Lee contacted Mutual and lost no time in signing an agreement, and the Mutual-Don Lee Network was born. This was how Mutual became the fourth coast-to-coast network, and it also marked the beginning of a new West Coast chain that would continue operation into the Fifties. The switch from CBS to Mutual was scheduled for December 29, 1936, the date which marked the expiration of the CBS - Don Lee contract. (In fact, for the last three months of the contract the CBS West Coast programs were produced at KNX and fed to KHJ for transmission to the network [34].) The stations on the new Mutual network were the four Don Lee-owned stations, plus KFXM San Bernardino, KDON Monterey, KXO El Centro, KPMC Bakersfield, KVOE Santa Ana, and KGDM Stockton [35]. Also joining the network via shortwave hookup were KGMB Honolulu and KHBC Hilo. A number of Pacific Northwest stations were added the following year.

These upheavals had a major impact on KFRC as a radio production center. The CBS network feeds from the East had reached the West Coast at San Francisco, and branched north and south from there. This had made KFRC the key CBS West Coast station. But the new Mutual hookup reached the Coast in Los Angeles, and KHJ became the key station. In the shakeup that followed these changes, most KFRC performers were either moved to KHJ or left to join other stations or networks. Key management personnel departed from both stations, including longtime KFRC manager Harrison Holliway who became the manager of KFI [32]. In short, the same forces that had caused the program exodus from San Francisco at NBC were at work within the Don Lee organization, and they occurred over the same period, 1936-1942.

SUMMARY

Almost all network program production had left San Francisco by 1942. After that time, the city still saw some national prominence as the network news center for the war in the Pacific. It was also the programming and transmission headquarters for several shortwave stations broadcasting to the Pacific by the Office of War Information (this was part of the genesis of the Voice of America). San Francisco also retained some importance as a facilities control point for the AT&T network. But it would never again see the prominence in broadcasting it experienced during its heyday of the late 1920s and early 1930s.



Radio networks in the West. Left: NBC (Red: dotted lines; Blue, dashed lines), as of 1936. Center: CBS (Purple), as of 1936. Right: MBS (Gold), as of 1938. These are "pricing diagrams"; the actual wire routing might differ slightly, as with the CBS feed to Santa Barbara, which was probably back-fed from Los Angeles.

REFERENCES

1. Interviews by author with Bill Andrews, former NBC announcer; San Francisco, Oct. 13, 1970, Nov. 2, 1970, Apr. 1, 1971.

2. Archer, Gleason L., Big Business and Radio (American Book - Stratford Press, Inc., 1939).

3. Broadcast Weekly Magazine, Aug. 24, 1929, p. 6.

4. San Francisco Chronicle, Apr. 1, 1927.

5. Shurick, E. P. J., First Quarter Century of American Broadcasting (Midland Publishing Company, 1946), p. 163.

6. Ibid., p. 416.

7. Manuscript: "Special to Radio Guide," by Louise Landis, Feature Ed., NBC, 111 Sutter Street, San Francisco, May 16, 1934; from KGO's history file.

8. Spaulding, John W., "1928: Radio Becomes a Mass Advertising Medium," Journal of Broadcasting, Vol. VIII, No. 1 (Winter 1963-64), pp. 31-44.

9. "Scoop," San Francisco Press Club, 1970.

10. Sheppard, Walter, "One Man's Family - A History and Analysis," unpublished doctoral dissertation, the University of Wisconsin, 1967; supplied by Carleton Morse.

11. Broadcasting Magazine, Jan. 1, 1936.

12. Broadcasting Magazine, Nov. 1, 1931; Apr. 1, 1933.

13. Press Release, "NBC Inaugurates Second Nationwide Network," 1936; from KGO's history file.

14. Higby, Mary Jane, Tune In Tomorrow, (Cowles Education Corporation, 1966), p. 22.

15. de Mare, George, "And Now We Take You To -- !", Western Electric Oscillator, Dec. 1945, p. 10.

16. Broadcasting Magazine, Nov. 1, 1938.

17. Broadcasting Magazine, Jan. 1, 1937.

18. Radio City souvenir dedication brochure, Apr. 25, 1942.

19. Roller, Albert F., "San Francisco's Radio City," Architectural Record Magazine, Nov. 1942.

20. San Francisco Examiner, Dec. 6, 1967.

21. Douglas, George H., The Early Days of Broadcasting (McFarland & Co., Inc., 1987), p. 140.

22. Broadcast Weekly Magazine, Aug. 24, 1929, p. 18.

23. Paper, Lewis J., Empire: William S. Paley and the Making of CBS (St. Martin's Press, New York, 1987), page 35.

24. 1935 Broadcasting Yearbook, Broadcasting Publications, Inc., Washington, D. C.

25. "KFRC, KHJ To Join CBS," Broadcast Weekly Magazine, Aug. 24, 1929, p. 18.

26. Various clippings from the scrapbook of Harrison Holliway, former KFRC manager; unpublished; loaned to the author by Holliway's former associate, Murray Bolen.

27. Letter to author by Murray Bolen, Apr. 14, 1971.

28. KFRC Press Release, dated Oct. 14, 1970.

29. Broadcasting Magazine, Sept. 15, 1934.

30. Broadcasting Magazine, Apr. 1, 1936.

31. Broadcasting Magazine, May 1, 1938.

32. Broadcasting Magazine, June 1, 1936.

33. Broadcasting Magazine, Dec. 15, 1936.

34. Told to author by Art Gilmore, former CBS announcer, June 2, 1990.

35. 1938 Broadcasting Yearbook, as [24].

John F. Schneider

John F. Schneider, KB7AK, began his research on this subject in the late 1960s, while a student in the Broadcast Communications Department of San Francisco State College. After graduation, he worked for a number of radio stations and broadcast equipment manufacturers in California and the Pacific Northwest. For the past eight years, he has operated his own company, RF Specialties of Washington, Inc., in Seattle, a broadcast equipment distributor. John is an avid collector of antique radios and microphones. He is currently President of the Puget Sound Antique Radio Association and Chairman of the Society of Broadcast Engineers, Chapter 16.

THE U.S. PATENTS OF ARMSTRONG, CONRAD, DE FOREST, DU MONT, FARNSWORTH, FESSENDEN, FLEMING, KENT, MARCONI, AND ZWORYKIN

David W. Kraeuter
Washington, PA

This compilation began innocently enough with a desire to find what inventions had been patented by Frank Conrad, a Pittsburgh radio pioneer. Later the patents of Reginald Fessenden, who also had worked in Pittsburgh, were added. I soon learned that although information was readily available on the inventions of Thomas Edison [Patents Granted to Thomas A. Edison, 1869-1918 (Washington, D. C.: Microfilm Publications, National Archives, 1981)] and Nikola Tesla [J. T. Ratzlaff, Dr. Nikola Tesla, Complete Patents (Millbrae, CA: Tesla Book Co., 1983)], information on the patents of some other radio and television inventors had never been assembled into a single, convenient source. Hence the present compilation, which makes available primary information about the 1,090 U. S. patents of Edwin Armstrong (51), Frank Conrad (178), Lee de Forest (216), Allen B. Du Mont (35), Philo T. Farnsworth (111), Reginald A. Fessenden (229), John A. Fleming (13), A. Atwater Kent (104), Guglielmo Marconi (39), and Vladimir Zworykin (114). Of course, many other names could be added to this list, but they will be left for a future article.

Most of the information herein has been derived from the indexes to the U. S. patents and generally has not been verified in the U. S. Patent Gazette. Although I worked very carefully in gathering this information, any work of this sort may contain errors. Anyone having corrections to make to the text is invited to write to the author, c/o Washington and Jefferson College, Washington, PA 15301.

I thank the staff of the Science and Technology Department at the Carnegie Library of Pittsburgh, where most of this information was gathered.

All patent citations take this form: Title. Number. Date. When the U. S. Patent Gazette reference is known, it is given as volume: page.

EDWIN ARMSTRONG (1890-1954)

Patents in Chronological (Patent Number) Order

Wireless receiving system. 1,113,149. October 6, 1914. 207:254.

Electric-wave transmission. 1,334,165. March 16, 1920. 272:489. [With Michael I. Pupin .]

Antenna with distributed positive resistance. 1,336,378. April 6, 1920. 273:127. [With Michael I. Pupin .]

Armstrong, cont.

Receiving high-frequency oscillations. 1,342,885. June 8, 1920. 275:303.
Multiple antenna for electrical wave transmission. 1,388,441. August 23, 1921. 289:674. [With Michael I. Pupin.]
Selectively opposing impedance to received electrical oscillations. 1,415,845. May 9, 1922. [With Michael I. Pupin.]
Radioreceiving system having high selectivity. 1,416,061. May 16, 1922. [With Michael I. Pupin.]
Tone-producing radioreceiver. 1,502,875. July 29, 1924. [With Michael I. Pupin.]
Wave signaling system. 1,539,820. June 2, 1925.
Wave signaling system. 1,539,821. June 2, 1925.
Wave signaling system. 1,539,822. June 2, 1925.
Wave signaling system. 1,541,780. June 16, 1925.
Wave-signaling system. 1,545,724. July 14, 1925.
Wireless receiving system for continuous waves. 1,611,848. December 21, 1926.
Wave signaling system. 1,675,323. July 3, 1928.
Wave signaling system. 1,716,573. June 11, 1929.
Radio signaling system. 1,941,066. December 26, 1933.
Radio broadcasting and receiving. 1,941,067. December 26, 1933.
Radiosignaling. 1,941,068. December 26, 1933.
Radiosignaling. 1,941,069. December 26, 1933.
Radiotelephone signaling. 1,941,447. December 26, 1933.
Radio signaling system. 2,024,138. December 17, 1935.
Radio transmitting system. 2,063,074. December 8, 1936.
Radio signaling system. 2,082,935. June 8, 1937.
Radio transmitting system. 2,098,698. November 9, 1937.
Radio signaling system. 2,104,011. January 4, 1938.
Multiplex radio signaling system. 2,104,012. January 4, 1938.
Radio receiving system. 2,116,501. May 10, 1938.
Radio receiving system. 2,116,502. May 10, 1938.
Frequency changing system. 2,122,401. July 5, 1938.
Radio transmitting system. 2,130,172. September 13, 1938.
Radio transmitting system. 2,169,212. August 15, 1939.
Radio transmitting system. 2,203,712. June 11, 1940.
Frequency modulation signaling system. 2,215,284. September 17, 1940.
Frequency modulation signaling system. Reissue 21,660. December 17, 1940.
Relaying frequency modulated signals. 2,264,608. December 2, 1941.
Relaying frequency modulated signals. 2,275,486. March 10, 1942.
Radio rebroadcasting system. 2,276,008. March 10, 1942.
Frequency modulation system. 2,290,159. July 21, 1942.
Current limiting device. 2,295,323. September 8, 1942.
Method and means for transmitting frequency modulated signals. 2,315,308. March 30, 1943.
Receiving radio signals. 2,318,137. May 4, 1943.
Frequency modulation signaling system. 2,323,698. July 6, 1943.
Frequency-modulated carrier signal receiver. 5,240,643. February 6, 1951.
Radio signaling. 2,602,885. July 18, 1952.
Frequency modulation multiplex system. 2,630,497. March 3, 1953.

Radio detection and ranging systems. 2,738,502. March 13, 1956. [Armstrong, Edwin H., deceased (E. M. Armstrong, executrix), J. H. Bose, and R. E. Hull.]

Multiplex frequency modulation transmitter. 2,773,125. December 4, 1956. [Armstrong, Edwin H., deceased (E. M. Armstrong, executrix).]

Linear detector for subcarrier frequency modulated waves. 2,835,803. May 20, 1958. [Bose, John H., to E. M. Armstrong, executrix of the estate of E. H. Armstrong.]

Noise reduction in phase shift modulation. 2,871,292. January 27, 1959. [Bose, John H., to E. M. Armstrong, executrix of the estate of E. H. Armstrong.]

Stabilized multiple frequency modulation receiver. 2,879,335. March 24, 1959. [Bose, John H., to E. M. Armstrong, executrix of the estate of E. H. Armstrong.]

Patents In Alphabetical Order

[See previous pages for complete citations.]

Antenna with distributed positive resistance. 1,336,378.
Current limiting device. 2,295,323.
Electric-wave transmission. 1,334,165.
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Frequency modulation multiplex system. 2,630,497; 2,215,284; 2,323,698.
Frequency modulation signaling system. Reissue 21,660. December 17, 1940.
Frequency modulation system. 2,290,159.
Linear detector for subcarrier frequency modulated waves. 2,835,803.
Method and means for transmitting frequency modulated signals. 2,315,308.
Multiple antenna for electrical wave transmission. 1,388,441.
Multiplex frequency modulation transmitter. 2,773,125.
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Radio detection and ranging systems. 2,738,502.
Radio rebroadcasting system. 2,276,008.
Radio receiving system. 2,116,501; 2,116,502.
Radio signaling. 2,602,885.
Radio signaling system. 1,941,066; 2,024,138; 2,082,935; 2,104,011.
Radio transmitting system. 2,063,074; 2,098,698; 2,130,172; 2,169,212; 2,203,712.
Radioreceiving system having high selectivity. 1,416,061.
Radiosignaling. 1,941,068; 1,941,069.
Radiotelephone signaling. 1,941,447.
Receiving high-frequency oscillations. 1,342,885.
Receiving radio signals. 2,318,137.
Relaying frequency modulated signals. 2,264,608; 2,275,486.
Selectively opposing impedance to received electrical oscillations. 1,415,845.
Stabilized multiple frequency modulation receiver. 2,879,335.
Tone-producing radioreceiver. 1,502,875.
Wave signaling system. 1,539,820; 1,539,821; 1,539,822; 1,541,789; 1,545,724;

1,675,323; 1,716,573.

Wireless receiving system. 1,113,149.

Wireless receiving system for continuous waves. 1,611,848.

FRANK CONRAD (1874-1941)

Patents In Chronological (Patent Number) Order

Electric-arc lamp. 599,931. March 1, 1898. 82:1305. [With Harry P. Davis.]

Electric meter and motor. 608,842. August 9, 1898. 84:914. [With Harry P. Davis.]

Alternating-current-measuring equipment. 611,466. September 27, 1898. 84:1962. [With Harry P. Davis.]

Alternating-current Voltmeter. 611,592. September 27, 1898. 84:2007. [With Harry P. Davis.]

Electrical measuring instrument. 627,908. June 27, 1899. [With Harry P. Davis.]

Electrical measuring instrument. 629,663. July 25, 1899. 88:673. [With Harry P. Davis.]

Instrument for indicating the phase and frequency relations of alternating currents. 695,913. March 25, 1902. 98:2375.

Means for measuring the energy of three-phase alternating-current circuits. 716,867. December 30, 1902. 101:2834.

Ground-detector for electric circuits. 716,868. December 30, 1902. 101:2835.

Measuring the energy of three-phase alternating-current circuits. 717,496. December 30, 1902. 101:3084.

Prepayment electrical measuring device. 757,439. April 19, 1904. 109:1897.

Alternating-current wattmeter. 760,426. May 24, 1904. 110:87.

Circuit making and breaking relay. 780,024. January 17, 1905. 114:551.

Constant current regulator. 792,120. June 13, 1905. 116:1796.

Electrical measuring instrument. 794,395. July 11, 1905. 117:400.

Measuring instrument. 798,167. August 29, 1905. 117:2414.

Spring-abutment for measuring instruments. 798,168. August 29, 1905. 117:2415.

Switch for electric circuits. 803,212. October 31, 1905. 118:2358. [With Arthur B. Reynders.]

Alternating-current system of control. 803,213. October 31, 1905. 118:2359.

Regulating means for systems of electrical distribution. 807,943. December 19, 1905. 119:2152. [With B. G. Lamme and C. F. Scott.]

Transformer. 829,572. August 28, 1906. 123:2740.

Protective apparatus for electrical circuits. 840,478. January 8, 1907. 126:404. [With Harry P. Davis.]

Protective apparatus for parallel transmission-lines. 840,479. January 8, 1907. 126:404. [With Harry P. Davis.]

Transformer. 841,076. January 8, 1907. 126:700.

Alternating-current electrical apparatus. 853,226. May 14, 1907. 128:472. [With William M. Bradshaw.]

Automatic synchronizer. 885,143. April 21, 1908. 133:1732.

Electric heating apparatus. 912,994. February 23, 1909. 139:740.

Conrad, cont.

Voltage-regulator. 923,627. June 1, 1909. 143:176.

System for vapor electric apparatus. 931,114. August 17, 1909. 145:549.

System of distribution for mercury-vapor rectifiers. 931,115. August 17, 1909. 145:550.

Overload and reverse current relay device. 933,746. Sep. 14, 1909. 146:266.

Overload and reverse current relay device. 934,390. Sep. 14, 1909. 146:478.

Overload and reverse current relay device. 934,391. Sep. 14, 1909. 146:478.

Electrical system. 934,596. September 21, 1909. 146:569.

Armature-winding. 954,614. April 12, 1910. 153:348.

Mercury-vapor rectifier. 969,525. September 6, 1910. 158:125.

Starting means for vapor-rectifying devices. 975,399. Nov. 15, 1910. 160:504.

Carbureter. 1,002,646. September 5, 1911. 170:154.

Transformer. 1,005,163. October 10, 1911. 171:235.

Prepayment-meter. 1,017,082. February 13, 1912. 175:329.

System of electric-motor control. 1,024,557. April 30, 1912. 177:1075.

Metering system. 1,029,743. June 18, 1912. 179:642.

Recording measuring instrument. 1,031,041. July 2, 1912. 180:67.

Recording measuring instrument. 1,031,042. July 2, 1912. 180:68.

Wattmeter. 1,067,311. July 15, 1913. 192:553.

Impedance device for use with current-rectifiers. 1,075,404. October 14, 1913. 195:309. [With Y. Sakai.]

Vapor electric device. 1,101,523. June 30, 1914. 203:1269.

Electrical apparatus. 1,106,368. August 11, 1914. 205:314.

System of distribution. 1,108,886. September 1, 1914. 206:7.

Current-rectifying device. 1,112,265. September 29, 1914. 206:1356.

Rectifier system. 1,112,266. September 29, 1914. 206:1357.

System of electrical distribution and regulation. 1,112,438. Oct. 6, 1914. 207:8.

Electrical regulator. 1,122,693. December 29, 1914. 209:1478.

Transformer for use with current-rectifying apparatus. 1,123,248. Jan. 5, 1915. 210:16.

Safety device for starting motors. 1,130,573. March 2, 1915. 212:257.

Overload and reverse current relay. 1,137,840. May 4, 1915. 214:41.

System of electrical distribution. 1,138,637. May 11, 1915. 214:358. [With Harry P. Davis.]

Electric measuring instrument. 1,141,380. June 1, 1915. 215:106.

Storage-battery regulator. 1,146,924. July 20, 1915. 216:722.

Electrical regulator. 1,146,925. July 20, 1915. 216:722.

Regulator for electrical circuits. 1,146,926. July 20, 1915. 216:723.

Electrical regulator. 1,146,927. July 20, 1915. 216:723.

Pressure-gage. 1,150,016. August 17, 1915. 217:712.

Protective means for electrical systems. 1,155,133. Sep. 28, 1915. 218:1068.

Means for protecting electrical systems. 1,155,134. Sep. 28, 1915. 218:1069.

Electrically operated device. 1,158,898. November 2, 1915. 220:171.

Vapor electric device. 1,159,900. Nov. 9, 1915. 220:557.

System of electrical distribution. 1,159,904. November 9, 1915. 220:558. [With Harry P. Davis.]

Starting means for vapor electric devices. 1,166,186. Dec. 28, 1915. 221:1333.

Conrad, cont.

Gear-wheel. 1,167,742. January 11, 1916. 222:516.
Gear. 1,167,743. January 11, 1916. 222:517.
Spark-advancer. 1,171,594. February 15, 1916. 223:721.
Vehicle-lighting system. 1,171,595. February 15, 1916. 223:721.
Interrupter. 1,171,596. February 15, 1916. 223:721.
Starting mechanism for automobiles. 1,175,342. March 14, 1916. 224:505.
Plug-connector. 1,175,343. March 14, 1916. 224:505.
Electrical system. 1,191,158. July 18, 1916. 228:774.
Starting-electrode for vapor electric devices. 1,194,143. Aug. 8, 1916. 229:505.
Vapor-rectifier. 1,204,411. November 14, 1916. 232:333.
Starting mechanism for automobiles. 1,215,490. February 13, 1917. 235:386. [With J. P. Nikonow.]
Ignition system. 1,219,704. March 20, 1917. 236:699.
System of electrical distribution. 1,224,143. May 1, 1917. 238:10.
Cut-out. 1,229,719. June 12, 1917. 239:502.
Vapor current-rectifying device. 1,234,875. July 31, 1917. 240:1225.
Electrical system. 1,234,876. July 31, 1917. 240:1225.
Electrical system. 1,235,012. July 31, 1917. 240:1270.
Starting and ignition machine. 1,237,172. August 14, 1917. 241:560.
Electrical system. 1,246,056. November 13, 1917. 244:303.
Starting mechanism for automobiles. 1,246,057. November 13, 1917. 244:304.
Starting system for automobiles. 1,246,717. November 13, 1917. 244:500.
Starting motor for gas-engines. 1,246,718. November 13, 1917. 244:500.
Ignition mechanism. 1,248,459. December 4, 1917. 245:9.
Electrical system for automobiles. 1,248,460. December 4, 1917. 245:9.
Regulator and cut-out. 1,260,647. March 26, 1918. 248:883.
Electrical system. 1,260,648. March 26, 1918. 248:884.
Regulator and cut-out. 1,260,649. March 26, 1918. 248:884.
Vapor-arc rectifier. 1,264,276. April 30, 1918. 249:1031.
Priming device for internal-combustion engines. 1,271,670. July 9, 1918. 252:290.
Starting system for automobiles. 1,274,992. August 6, 1918. 253:185.
Ignition mechanism. 1,277,388. September 3, 1918. 254:16.
Vapor electric apparatus. 1,285,947. November 26, 1918. 256:749.
Side lamp for automobiles. 1,296,482. March 4, 1919. 260:148.
Gear-shifting mechanism. 1,296,483. March 4, 1919. 260:148.
Hand-grenade. 1,304,544. May 27, 1919. 262:492.
Radiotelegraphy system. 1,314,789. September 2, 1919. 266:59.
Starting mechanism for gas-engines. 1,317,269. September 30, 1919. 266:625.
Connector. 1,318,728. October 14, 1919. 267:265.
System of electrical distribution. 1,320,083. October 28, 1919. 267:570. [With Charles M. Moss, F. C. Hanker, and H. A. Travers.]
Ignition system. 1,338,360. April 27, 1920. 273:708. [With J. S. Kinney.]
Mounting for oil-pumps. 1,344,756. June 29, 1920. 275:863.
Ignition system. 1,352,431. September 14, 1920. 278:173.
Electrical ignition system. 1,352,432. September 14, 1920. 278:173.
Electrical ignition system. 1,352,433. September 14, 1920. 278:173.
Ignition system. 1,352,434. September 14, 1920. 278:173.

Conrad, cont.

Gear-shift mechanism. 1,363,719. December 28, 1920. 281:677.
Starting mechanism for gas engines. 1,370,005. March 1, 1921. 284:48.
Starting mechanism for automobiles. 1,385,983. August 2, 1921. 289:4.
Starting mechanism for internal-combustion engines. 1,413,829. April 25, 1922.
Distributor for ignition apparatus. 1,417,717. May 30, 1922.
Apparatus for the receipt of wireless impulses. 1,456,867. May 29, 1923.
Spark-advancing mechanism. 1,466,272. August 28, 1923.
Radiomodulation system. 1,477,316. December 11, 1923.
Tuning system of antennae. 1,502,848. July 29, 1924.
Receiving circuit for the elimination of static disturbances. 1,513,223. Oct. 28, 1924.
Aperiodic receiver system. 1,515,186. November 11, 1924.
Wireless telephone system. 1,528,047. March 3, 1925.
Regulator system. 1,543,696. June 30, 1925.
Signaling system. 1,563,342. December 1, 1925.
Volt-ampere meter. 1,571,234. February 2, 1926.
Wireless transmission system. 1,586,653. June 1, 1926.
Inductance device. 1,635,541. July 12, 1927.
Wireless antenna system. 1,640,534. August 30, 1927.
Polyphase plate-circuit excitation system. 1,645,291. October 11, 1927. [With John O. Nyman.]
Radio transmitting system. 1,652,516. December 13, 1927.
Radio sending system. 1,654,322. December 27, 1927.
Wireless receiving cabinet. 1,655,985. January 10, 1928.
Telephone device. 1,660,864. February 28, 1928.
Wireless receiving set. 1,664,192. March 27, 1928.
Telephone device. 1,680,409. August 14, 1928.
Directive antenna system. 1,689,863. October 30, 1928.
Aerial system. 1,691,338. November 13, 1928.
Telephone circuits and apparatus. 1,693,401. Nov. 27, 1928. [With A. Nyman.]
Electrical measuring instrument. 1,695,917. December 18, 1928.
Inductor helix. 1,702,461. February 19, 1929.
Multiple electrode vacuum tube. 1,709,659. April 16, 1929.
Insulator. 1,730,124. October 1, 1929.
Duplex radio transmission system. 1,732,741. October 22, 1929.
Antenna system. 1,750,347. March 11, 1930.
Short-wave antenna. 1,768,666. July 1, 1930.
Frequency-control device. 1,768,888. July 1, 1930. [With John B. Coleman.]
Modulation system. 1,799,974. April 7, 1931.
Telephone receiver. 1,819,499. August 18, 1931.
Condenser. 1,837,017. December 15, 1931.
Television system. 1,853,661. April 12, 1932.
Constant frequency generator. 1,872,896. August 23, 1932.
Radio relay system. 1,877,815. September 20, 1932.
Electric clock. 1,911,062. May 23, 1933.
Control device. 1,934,524. November 7, 1933.
Motion-picture apparatus. 1,939,031. Dec. 12, 1933. [With Christian Aalborg.]

Conrad, cont.

Transmission system. 1,939,042. December 12, 1933.

Refrigerator. 1,982,375. November 27, 1934. [With Christian Aalborg.]

Television apparatus. 1,991,082. February 12, 1935.

Motion picture apparatus. 2,023,065. December 3, 1935.

Motion picture apparatus. 2,032,116. February 25, 1936. [With C. Aalborg, O. B. French, and N. J. Collingswood.]

Refrigerator apparatus. 2,056,646. October 6, 1936.

Radio communication system. 2,057,640. October 13, 1936.

Battery-charging system. 2,117,018. May 10, 1938. [With G. C. Goode.]

Double-winding generator and rectifier combination. 2,117,019. May 10, 1938.

Copper-oxide rectifier. 2,117,020. May 10, 1938.

Time switch. 2,121,585. June 21, 1938.

Motion picture apparatus. 2,123,624. July 12, 1938. [With C. Aalborg and O. B. French.]

Refrigerating apparatus. 2,148,412. February 21, 1939.

Receiving system. 2,151,747. March 28, 1939.

Alternating-current direct-current clock. 2,183,062. December 12, 1939.

Air conditioning system. 2,205,744. June 25, 1940.

Automobile battery charging system and flat rectifier therefor. 2,217,471. October 8, 1940.

Automotive generating system. 2,233,586. March 4, 1941.

Manufacture of copper-oxide rectifiers. 2,276,647. March 17, 1942. [With E. D. Wilson, C. C. Hein, and F. T. Hague.]

Patents In Alphabetical Order

[See previous pages for complete citations.]

Aerial system. 1,691,338.

Air conditioning system. 2,205,744.

Alternating-current direct-current clock. 2,183,062.

Alternating-current electrical apparatus. 853,226.

Alternating-current-measuring equipment. 611,466.

Alternating-current system of control. 803,213.

Alternating-current voltmeter. 611,592.

Alternating-current wattmeter. 760,426.

Antenna system. 1,750,347.

Aperiodic receiver system. 1,515,186.

Apparatus for the receipt of wireless impulses. 1,456,867.

Armature-winding. 954,614.

Automatic synchronizer. 885,143.

Automobile battery charging system and flat rectifier therefor. 2,217,471.

Automotive generating system. 2,233,586.

Battery-charging system. 2,117,018.

Carbureter. 1,002,646.

Circuit making and breaking relay. 780,024.

Condenser. 1,837,017.

Connector. 1,318,728.

Conrad, cont.

Storage-battery regulator. 1,146,924.
Switch for electric circuits. 803,212.
System for vapor electric apparatus. 931,114.
System of distribution. 1,108,886.
System of distribution for mercury-vapor rectifiers. 931,115.
System of electric-motor control. 1,024,557.
System of electrical distribution. 1,138,637; 1,159,904; 1,224,143; 1,320,083.
System of electrical distribution and regulation. 1,112,438.
Telephone circuits and apparatus. 1,693,401.
Telephone device. 1,660,864; 1,680,409.
Telephone receiver. 1,819,499.
Television apparatus. 1,991,082.
Television system. 1,853,661.
Time switch. 2,121,585.
Transformer. 829,572; 841,076; 1,005,163.
Transformer for use with current-rectifying apparatus. 1,123,248.
Transmission system. 1,939,042.
Tuning system of antennae. 1,502,848.
Vapor-arc rectifier. 1,264,276.
Vapor current-rectifying device. 1,234,875.
Vapor electric apparatus. 1,285,947.
Vapor electric device. 1,101,523; 1,159,900.
Vapor-rectifier. 1,204,411.
Vehicle-lighting system. 1,171,595.
Volt-ampere meter. 1,571,234.
Voltage-regulator. 923,627.
Wattmeter. 1,067,311.
Wireless antenna system. 1,640,534.
Wireless receiving cabinet. 1,655,985.
Wireless receiving set. 1,664,192.
Wireless telephone system. 1,528,047.
Wireless transmission system. 1,586,653.

LEE DE FOREST (1873-1961)

Patents In Chronological (Patent Number) Order

[Note: Patents assigned to any of the various de Forest companies but not in de Forest's name are not listed.]

Apparatus for communicating signals through space. 716,000. December 16, 1902. 101:2412. [With E. H. Smythe.]
Wireless telegraphy. 716,203. Dec. 16, 1902. 101:2501. [With E. H. Smythe.]
Communicating signals through space. 716,334. December 16, 1902. 101:2548. [With E. H. Smythe.]
Space telegraphy. 720,568. February 17, 1903. 102:1308.
Space telegraphy. 730,246. June 9, 1903. 104:1412.
Wireless telegraphy. 730,247. June 9, 1903. 104:1412.
Wireless signaling. 730,819. June 9, 1903. 104:1629.

de Forest, cont.

Wireless signaling device. 748,597. January 5, 1904. 108:19.
Wireless signaling apparatus. 749,131. January 5, 1904. 108:269.
Wireless signaling apparatus. 749,178. January 12, 1904. 108:314.
Wireless-telegraph receiver. 749,371. January 12, 1904. 108:403.
Wireless telegraphy. 749,372. January 12, 1904. 108:404.
Wireless signaling device. 749,434. January 12, 1904. 108:429.
Generating set for wireless telegraphy. 749,435. January 12, 1904. 108:429.
Wireless-telegraph range finder. 749,436. January 12, 1904. 108:430.
Controlling spark production. 750,180. January 19, 1904. 108:758.
Device for clearing ice from antennae. 750,181. January 19, 1904. 108:758.
Wireless telegraphy. 758,517. April 26, 1904. 109:2389.
Wireless signaling apparatus. 759,216. May 3, 1904. 110:291.
Receiver for space signaling. 770,228. September 13, 1904. 112:478.
Wireless signaling apparatus. 770,229. September 13, 1904. 112:478.
Wireless signaling apparatus. 771,818. October 11, 1904. 112:1226.
Wireless signaling apparatus. 771,819. October 11, 1904. 112:1227.
Protecting device for high-frequency apparatus. 771,820. Oct. 11, 1904. 112:1227.
Magnetic decoder. 772,878. October 18, 1904. 112:1718.
Duplex wireless telegraphy. 772,879. October 18, 1904. 112:1719.
Wireless-telegraph system. 806,966. December 12, 1905. 119:1689.
Wireless-telegraph system. 822,936. June 12, 1906. 122:2080.
Static valve for wireless-telegraph systems. 823,402. June 12, 1906. 122:2289.
Wireless-telegraph system. 824,003. June 19, 1906. 122:2606.
Oscillation-responsive device. 824,637. June 26, 1906. 122:2929.
Oscillation-responsive device. 824,638. June 26, 1906. 122:2930.
Wireless-telegraph system. 827,523. July 31, 1906. 123:1542.
Wireless-telegraph system. 827,524. July 31, 1906. 123:1543.
Aerophore. 833,034. October 9, 1906. 124:1739.
Aerophore. 836,015. November 13, 1906. 125:587.
Oscillation-responsive device. 836,070. November 13, 1906. 125:613.
Oscillation-responsive device. 836,071. November 13, 1906. 125:613.
Aerophore. 836,072. November 13, 1906. 125:614.
Wireless telegraphy. 837,901. December 4, 1906. 125:1658.
Wireless telegraphy. 841,386. Jan. 15, 1907. 126:906.
Device for amplifying feeble electrical currents. 841,387. Jan. 15, 1907. 126:908.
Space telegraphy. 850,917. April 23, 1907. 127:2834.
Wireless-telegraph receiving system. 852,381. April 30, 1907. 127:3599.
Oscillation responsive device. 867,876. October 8, 1907. 130:1638.
Detecting oscillations. 867,877. October 8, 1907. 130:1639.
Oscillation-detector. 867,878. October 8, 1907. 130:1639.
Cautery. 874,178. December 17, 1907. 131:1849.
Wireless-telegraph transmitting system. 876,165. January 7, 1908. 132:158.
Magnetic detector. 877,069. January 21, 1908. 132:531.
Space telegraphy. 879,532. February 18, 1908. 132:1458.
Electrode for electrolytic or liquid oscillation-detectors for wireless telegraphy. 894,317. July 28, 1908. 135:717.
Aerophore. 894,318. July 28, 1908. 135:717.

de Forest, cont.

Wireless signaling apparatus. 894,378. July 28, 1908. 135:736.
Space telegraphy. 913,718. March 2, 1909. 140:16.
Wireless telegraphy. 926,933. July 6, 1909. 144:76.
Wireless-telegraph tuning device. 926,934. July 6, 1909. 144:77.
Wireless-telegraph transmitter. 926,935. July 6, 1909. 144:77.
Space telegraphy. 926,936. July 6, 1909. 144:77.
Space telephony. 926,937. July 6, 1909. 144:78.
Space telegraphy. 943,969. December 21, 1909. 149:720.
Transmitting apparatus. 966,539. August 9, 1910. 157:260.
Aerophore. 973,644. October 25, 1910. 159:815.
Oscillation-responsive device. 979,275. December 20, 1910. 161:696.
Space telegraphy. 979,276. Dec. 20, 1910. 161:696.
High-frequency electrical-oscillation generator. 979,277. Dec. 20, 1910. 161:697.
System for amplifying feeble electric currents. 995,126. June 13, 1911. 167:391.
Space telegraphy. 995,339. June 13, 1911. 167:461.
Space telephony. 1,006,635. October 24, 1911. 171:818.
Space telephony. 1,006,636. October 24, 1911. 171:818.
Transmission of music by electromagnetic waves. 1,025,908. May 7, 1912. 178:275.
Score-card. 1,026,433. May 14, 1912. 178:491.
System of duplex wireless transmission. 1,042,205. October 22, 1912. 183:955.
Wireless telegraphy. 1,101,533. June 30, 1914. 203:1273.
Signaling system. 1,123,118. Dec. 29, 1914. 209:1626.
Secrecy system for wireless communication. 1,123,119. Dec. 29, 1914. 209:1627.
Arc mechanism for systems of space communications. 1,123,120. Dec. 29, 1914. 209:1627.
Wireless-telephone transmitting system. 1,125,496. January 19, 1915. 210:888.
Receiving system for electromagnetic radiations. 1,134,593. April 6, 1915. 213:186.
Means for increasing the strength of electric currents. 1,134,594. April 6, 1915. 213:187.
Wireless receiving system. 1,170,881. February 8, 1916. 223:428.
Automatic switching device for telephone systems. 1,170,882. Feb. 8, 1916. 223:428.
Spark-gap for radiotone wireless-telegraph systems. 1,171,598. Feb. 15, 1916. 223:722.
Apparatus for and method of recording fluctuating currents. 1,177,848. April 4, 1916. 225:94.
Range-teller. 1,183,802. May 16, 1916. 226:1030.
Wireless telephone system. 1,183,803. May 16, 1916. 226:1031.
Quench-spark discharger. 1,190,869. July 11, 1916. 228:631.
Oscillating-current generator. 1,201,270. October 17, 1916. 231:624.
Oscillating audion. 1,201,271. October 17, 1916. 231:624.
Telegraph and telephone receiving system. 1,201,272. Oct. 17, 1916. 231:625.
Oscillation-generator. 1,201,273. October 17, 1916. 231:625.
Wireless telegraphy. 1,214,283. January 30, 1917. 234:1479.
Wireless-telegraph signaling system. 1,221,033. April 3, 1917. 237:11.
Oscillating-current generator. 1,221,034. April 3, 1917. 237:11.

Apparatus for use in wire or radio communications. 1,221,035. April 3, 1917. 237:11.
Metallic audion. 1,230,874. June 26, 1917. 239:959.
Apparatus for use in radiocommunication. 1,299,356. April 1, 1919. 261:168.
Means for transforming mechanical vibrations into electrical vibrations. 1,309,753. July 15, 1919. 264:388.
Oscillation-generator. 1,311,264. July 29, 1919. 264:729.
Method of and means for reproducing and amplifying weak pulsating currents. 1,314,250. August 26, 1919. 265:538.
Radiotelephony. 1,314,251. August 26, 1919. 265:538.
Oscillation-generator. 1,314,252. August 26, 1919. 265:538.
Apparatus for use in wire or radio communications. 1,314,253. Aug. 26, 1919. 265:538.
Oscillating-current generator. 1,329,758. February 3, 1920. 271:77.
Apparatus for amplifying pulsating electric currents. 1,348,157. Aug. 3, 1920. 277:5.
Radio-telephone system. 1,348,213. August 3, 1920. 277:16.
Wireless telephone system. Reissue 14,959. October 19, 1920. 279:497.
Apparatus for use in telegraphy or telephony. 1,365,157. Jan. 11, 1921 282:258.
Endless-film arrangement. 1,365,237. January 11, 1921. 282:273.
Means for amplifying currents. 1,375,447. April 19, 1921. 285:503.
Audion-circuit. 1,377,405. May 10, 1921. 286:253.
Selective audion amplifier. 1,397,575. November 22, 1921.
Radiosignaling system. 1,417,662. May 30, 1922.
Subterranean signaling system. 1,424,805. August 8, 1922.
Oscillion. 1,437,498. December 5, 1922.
Sound-controlled means for producing light variations. 1,442,426. Jan. 16, 1923.
Endless sound record and mechanism therefor. 1,442,682. January 16, 1923.
Means for transforming mechanical vibrations into electrical vibrations. Reissue 15,540. February 13, 1923.
Means for recording and reproducing sound. 1,446,246. February 20, 1923.
Light-controlling means. 1,446,247. February 20, 1923.
Telephone device. 1,452,827. April 24, 1923.
Method of and means for controlling electric currents by and in accordance with light variation. 1,466,701. September 4, 1923.
Radio receiving system. 1,478,029. December 18, 1923.
Means for recording and reproducing sound. 1,482,119. January 29, 1924.
Sound producer. 1,486,866. March 18, 1924.
Recording sound. 1,489,314. April 8, 1924.
Radio signaling system. 1,507,016. September 2, 1924.
Wireless telegraph and telephone system. 1,507,017. September 2, 1924.
Communication system for railway trains. 1,515,152. November 11, 1924.
Thermophone. 1,526,778. February 17, 1925.
Electrical means for producing musical notes. 1,543,990. June 30, 1925.
Telephone device. 1,552,914. September 8, 1925.
Sound-reproducing mechanism. 1,554,561. September 22, 1925.
Loud-speaking device. 1,554,794. September 22, 1925.
Radio signaling system. 1,554,795. September 22, 1925.
Sound-reproducing device. 1,560,502. November 3, 1925.

de Forest, cont.

Indicating device for fluid tanks. 1,561,596. November 17, 1925.
Loud speaker. 69,443. February 16, 1926.
Railway signaling system. 1,610,692. Dec. 14, 1926. [Charles V. Logwood, assignor.]
Recording sound. 1,618,641. February 22, 1927.
Slot cleaner for motion-picture machines. 1,629,152. May 17, 1927.
Electrical sound-reproducing apparatus. 1,641,664. September 6, 1927.
Telephone device. 1,642,363. September 13, 1927.
Talking-moving-picture equipment. 1,653,155. December 20, 1927.
Film-protecting arrangement. 1,659,909. February 21, 1928.
Slot cleaner for phonofilm attachment for motion-picture machines. 1,659,910. Feb. 21, 1928.
Radio signaling system. 1,680,207. August 7, 1928.
Sound recording and reproducing apparatus. 1,683,451. September 4, 1928.
Radio transmitting system. 1,687,364. October 9, 1928.
Sound-recording attachment for motion-picture cameras. 1,693,071. Nov. 27, 1928.
Shielding sound detector and amplifier apparatus. 1,693,072. Nov. 27, 1928.
Talking-moving-picture machine. 1,695,414. December 18, 1928.
Talking-moving-picture record. 1,695,415. December 18, 1928.
Acoustic apparatus. 1,701,911. February 12, 1929.
Motion-picture screen. 1,710,922. April 30, 1929.
Producing talking-motion-picture films and apparatus used therefor. 1,716,033. June 4, 1929.
Loud-speaker motor. 1,718,337. June 25, 1929.
Radio receiving apparatus. 1,720,544. July 9, 1929.
Photo-electric cell. 1,722,280. July 30, 1929.
Diffraction microphone. 1,726,289. August 27, 1929.
Sound-reproducing device. 1,736,035. November 19, 1929.
Sound actuated and producing device. 1,738,988. December 10, 1929.
Wireless telegraph and telephone system. 1,740,577. December 24, 1929.
Sound and picture recording camera. 1,761,619. June 3, 1930.
Producing talking-motion-picture films. 1,764,938. June 17, 1930.
Sound-reproducing device. 1,766,612. June 24, 1930.
Binaural recording and reproducing sound. 1,769,907. July 1, 1930.
Recording and reproducing sound. 1,769,908. July 1, 1930.
Switch mechanism for talking-motion-picture-exciting lamps. 1,769,909. July 1, 1930.
Binaural recording and reproducing sound. 1,777,037. September 30, 1930.
Sound-picture photography. 1,777,828. October 7, 1930.
Loud-speaker. 1,785,377. December 16, 1930. [With R. Halpenny.]
Sound reproducer. 1,795,936. March 10, 1931.
Automatic photographic sound reproducing mechanism. 1,802,595. April 28, 1931.
Silent drive mechanism for talking motion picture machines. 1,806,744. May 26, 1931.
Sound producing device. 1,806,745. May 26, 1931.
Luminous discharge device. 1,806,746. May 26, 1931.
Talking motion pictures and obliterating stipulated portion or portions therefor. Reissue 18,108. June 23, 1931.
Sound-chamber and set-frame therefor. 1,812,687. June 30, 1931.
Sound reproducer. 1,827,283. October 13, 1931.

de Forest, cont.

Microphone. 1,834,051. December 1, 1931.

Talking motion picture apparatus. 1,843,972. February 9, 1932.

Sound reproducing device. 1,853,850. April 12, 1932.

Sound-on-film phonograph. 1,859,435. May 24, 1932.

Sound reproducing device. 1,866,090. July 5, 1932.

Gaseous discharge device. 1,873,558. August 23, 1932.

Talking motion picture attachment. 1,885,900. November 1, 1932.

Securing synchronization in talking motion picture photography. 1,888,910. November 22, 1932.

Photographic sound reproducing apparatus. 1,894,024. January 10, 1933.

Luminous discharge device. 1,897,363. February 14, 1933.

Soundproofing picture recording camera. 1,929,626. October 10, 1933.

Gaseous discharge device. 1,944,929. January 30, 1934.

Apparatus for reproducing sound-on-film. 1,992,201. February 26, 1935.

Television receiving and projecting. 2,003,680. June 4, 1935.

Television receiving method and apparatus. 2,026,872. January 7, 1936.

Apparatus for receiving and projecting televised images in synchronism with sound. 2,045,570. June 30, 1936.

Television sign. 2,049,763. August 4, 1936.

Television apparatus. 2,052,133. August 25, 1936.

Apparatus for reproducing sound-on-film. 2,064,593. December 15, 1936.

Television system and method. 2,122,456. July 5, 1938.

High frequency oscillating circuit. 2,126,541. August 9, 1938.

Radial scanning television system. 2,163,749. June 27, 1939.

Television radial scanning system employing cathode beam. [Assigned to R. C. Gilman, Waterbury, Conn.] 2,241,809. May 13, 1941.

Method of and apparatus for determining the ground speed and/or course of aircraft. 2,391,554. December 25, 1945.

Altitude determination. 2,410,868. November 12, 1946.

Method of and apparatus for determining absolute altitude. 2,421,248. May 27, 1947.

Color television system. 2,452,293. October 26, 1948.

Method of and apparatus for bunching electrons. 2,457,980. January 4, 1949.

Cathode beam tube. 2,457,981. January 4, 1949.

Frequency modulating device. 2,462,367. February 22, 1949.

High-voltage generator. 2,489,082. November 22, 1949.

Electronic light amplifier. 2,594,740. April 29, 1952. [With W. A. Rhodes.]

Apparatus for color television. 2,617,875. November 11, 1952.

Transistor. 2,735,049. February 14, 1956.

Method and apparatus for recording and reproducing television pictures. 2,743,318. April 24, 1956.

Automatic dialing device for dial telephones. 2,813,931. November 19, 1957.

Patents In Alphabetical Order

[See previous pages for complete citations.]

Acoustic apparatus. 1,701,911.

de Forest, cont.

Luminous discharge device. 1,806,746; 1,897,363.
Magnetic decoder. 772,878.
Magnetic detector. 877,069.
Means for amplifying currents. 1,375,447.
Means for increasing the strength of electric currents. 1,134,594.
Means for recording and reproducing sound. 1,446,246; 1,482,119.
Means for transforming mechanical vibrations into electrical vibrations. Reissue 15,540. February 13, 1923.
Means for transforming mechanical vibrations into electrical vibrations. 1,309,753.
Metallic audion. 1,230,874.
Method and apparatus for recording and reproducing television pictures. 2,743,318.
Method of and apparatus for bunching electrons. 2,457,980.
Method of and apparatus for determining absolute altitude. 2,421,248.
Method of and apparatus for determining the ground speed and/or course of aircraft. 2,391,554.
Method of and means for controlling electric currents by and in accordance with light variation. 1,466,701.
Method of and means for reproducing and amplifying weak pulsating currents. 1,314,250.
Microphone. 1,834,051.
Motion-picture screen. 1,710,922.
Oscillating audion. 1,201,271.
Oscillating-current generator. 1,201,270; 1,221,034; 1,329,758.
Oscillation-detector. 867,878.
Oscillation-generator. 1,201,273; 1,311,264; 1,314,252.
Oscillation
Oscillion. 1,437,498.
Photo-electric cell. 1,722,280.
Photographic sound reproducing apparatus. 1,894,024.
Producing talking-motion-picture films. 1,764,938.
Producing talking-motion-picture films and apparatus used therefor. 1,716,033.
Protecting device for high-frequency apparatus. 771,820.
Quench-spark discharger. 1,190,869.
Radial scanning television system. 2,163,749.
Radio receiving apparatus. 1,720,544.
Radio receiving system. 1,478,029.
Radiosignaling system. 1,417,662.
Radio signaling system. 1,507,016; 1,554,795; 1,680,207.
Radio-telephone system. 1,348,213.
Radiotelephony. 1,314,251.
Radio transmitting system. 1,687,364.
Railway signaling system. 1,610,692.
Range-teller. 1,183,802.
Receiver for space signaling. 770,228.
Receiving system for electromagnetic radiations. 1,134,593.
Recording and reproducing sound. 1,769,908.
Recording sound. 1,489,314; 1,618,641.

de Forest, cont.

Thermophone. 1,526,778.
Transistor. 2,735,049.
Transmission of music by electromagnetic waves. 1,025,908.
Transmitting apparatus. 966,539.
Wireless receiving system. 1,170,881.
Wireless signaling. 730,819.
Wireless signaling apparatus. 749,131; 749,178; 759,216; 770,229; 771,818; 771,819; 894,378.
Wireless signaling device. 748,597; 749,434.
Wireless telegraph and telephone system. 1,507,017; 1,740,577.
Wireless-telegraph range finder. 749,436.
Wireless-telegraph receiver. 749,371.
Wireless-telegraph receiving system. 852,381.
Wireless-telegraph signaling system. 1,221,033.
Wireless-telegraph system. 806,966; 822,936; 824,003; 827,523; 827,524.
Wireless-telegraph transmitter. 926,935.
Wireless-telegraph transmitting system. 876,165.
Wireless-telegraph tuning device. 926,934.
Wireless telegraphy. 716,203; 730,247; 749,372; 758,517; 837,901; 841,386; 926,933; 1,101,533; 1,214,283.
Wireless telephone system. Reissue 14,959. October 19, 1920.
Wireless telephone system. 1,183,803.
Wireless-telephone transmitting system. 1,125,496.

ALLEN B. DU MONT (1901-1965)

Patents In Chronological (Patent Number) Order

[Note: Patents assigned to Allen B. Du Mont Laboratories but not in Du Mont's name are not listed.]

Mount for radiotubes. 1,719,968. July 9, 1929.
Apparatus and method for testing electrical devices. 1,814,437. July 14, 1931.
Sound operated circuit controller. 1,844,117. February 9, 1932.
Multiple electrode radiotron. 1,857,589. May 10, 1932. [With P. T. Weeks.]
Radiotube. 1,898,351. February 21, 1933.
Ultra-high frequency generating system. 1,915,356. June 27, 1933.
Automatic testing apparatus. 1,916,364. July 4, 1933.
Filament. 1,924,543. August 29, 1933.
Rectifier device. 1,924,544. August 29, 1933.
Automatic aging and testing method and mechanism. 1,955,794. April 24, 1934. [With R. M. Zimber.]
Cathode ray instrument for measuring electrical quantities. 1,960,333. May 29, 1934.
Exhaust machine. 1,967,571. July 24, 1934. [With R. M. Zimber.]
Television system. 1,984,673. December 18, 1934.
Electron turbine. 1,999, 407. April 30, 1935.
Telautograph. 2,000,014. May 7, 1935.
Voltmeter for vacuum tubes. 2,014,106. September 10, 1935.
Synchronous electron motor. 2,067,382. January 12, 1937.

Du Mont, cont.

Current generator and converter. 2,082,327. June 1, 1937.
Commutating device. 2,085,576. June 29, 1937.
Cathode ray tube. 2,087,280. July 20, 1937.
Cathode ray device. 2,098,231. November 9, 1937.
Cathautograph. 2,185,705. January 2, 1940.
Method and system for television communication. 2,186,634. January 9, 1940.
Cathode ray tube. 2,186,635. January 9, 1940.
Television transmitting system. 2,207,048. July 9, 1940. [With Richard L. Campbell.]
Synchronizing generator. 2,209,507. July 30, 1940. [With Richard L. Campbell.]
Cathode ray tube. 2,225,099. December 17, 1940. [With Peter S. Christaldi.]
Cathode-ray tube control device for television scanning apparatus. 2,229,556. January 21, 1941. [With T. T. Goldsmith.]
Monitoring and control system. 2,297,752. October 6, 1942. [With T. T. Goldsmith.]
Method and system for television communication. 2,299,471. October 20, 1942. [With T. T. Goldsmith.]
System for color television receivers. 2,337,980. December 28, 1943. [With T. T. Goldsmith.]
Photovision. 2,472,889. June 14, 1949.
Projection screen. 2,521,571. September 5, 1950. [With T. T. Goldsmith.]
Adjacent area illuminator for cathode-ray tubes. 2,669,708. February 16, 1954.
Dual image viewing apparatus. 2,832,821. April 29, 1958.

Patents In Alphabetical Order

[See previous pages for complete citations.]

Adjacent area illuminator for cathode-ray tubes. 2,669,708.
Apparatus and method for testing electrical devices. 1,814,437.
Automatic aging and testing method and mechanism. 1,955,794.
Automatic testing apparatus. 1,916,364.
Cathautograph. 2,185,705.
Cathode ray tube. 2,087,280; 2,186,635; 2,225,099.
Cathode ray device. 2,098,231.
Cathode ray instrument for measuring electrical quantities. 1,960,333.
Cathode-ray tube control device for television scanning apparatus. 2,229,556.
Commutating device. 2,085,576.
Current generator and converter. 2,082,327.
Dual image viewing apparatus. 2,832,821.
Electron turbine. 1,999, 407.
Exhaust machine. 1,967,571.
Filament. 1,924,543.
Method and system for television communication. 2,186,634; 2,299,471.
Monitoring and control system. 2,297,752.
Mount for radiotubes. 1,719,968.
Multiple electrode radiotron. 1,857,589.
Photovision. 2,472,889.

Du Mont, cont.
Projection screen. 2,521,571.
Radiotube. 1,898,351.
Rectifier device. 1,924,544.
Sound operated circuit controller. 1,844,117.
Synchronizing generator. 2,209,507.
Synchronous electron motor. 2,067,382.
System for color television receivers. 2,337,980.
Television system. 1,984,673.
Television transmitting system. 2,207,048.
Telautograph. 2,000,014.
Ultra-high frequency generating system. 1,915,356.
Voltmeter for vacuum tubes. 2,014,106.

PHILO T. FARNSWORTH (1906-1971)
Patents In Chronological (Patent Number) Order

[Note: Patents assigned to Farnsworth Television and Radio Corporation but not in Farnsworth's name are not listed.]

Electric oscillator system. 1,758,359. May 13, 1930.
Television system. 1,773,980. August 26, 1930.
Television receiving system. 1,773,981. August 26, 1930.
Light valve. 1,806,935. May 26, 1931.
Synchronizing system. 1,844,949. February 16, 1932.
Dissector target. 1,941,344. December 26, 1933.
Electron multiplier. 1,969,399. August 7, 1934.
Photoelectric apparatus. 1,970,036. August 14, 1934.
Thermionic vacuum tube. 1,975,143. October 2, 1934.
Electrical discharge apparatus. 1,986,330. January 1, 1935.
Admittance neutralizing amplifier. 1,986,331. January 1, 1935.
System of pulse transmission. 2,026,379. December 31, 1935.
Method and apparatus for television. 2,037,711. April 21, 1936.
Scanning and synchronizing system. 2,051,372. August 18, 1936.
Slope wave generator. 2,059,219. November 3, 1936.
Scanning oscillator. 2,059,683. November 3, 1936.
Incandescent light source. 2,066,070. December 29, 1936.
Luminescent screen and use. 2,104,253. January 4, 1938.
Radiation frequency converter. 2,107,782. Feb. 8, 1938. [With D. K. Lippincott.]
High power projection oscillograph. 2,109,289. Feb. 22, 1938. [With F. J. Somers.]
Image receiving tube. 2,118,186. May 24, 1938.
Electron multiplier. Reissue 20,759. June 14, 1938.
Beam scanning dissector. 2,124,057. July 19, 1938.
Operating electron multipliers. 2,128,580. August 20, 1938.
Multipactor. 2,135,615. November 8, 1938.
Multipactor oscillator. 2,137,528. November 22, 1938.
Secondary emission electrode. 2,139,813. December 13, 1938.
Cathode ray tube. 2,139,814. December 13, 1938.
Projecting oscillight. 2,140,284. December 13, 1938.

Farnsworth, cont.

Multiplier coupling system. 2,140,285. December 13, 1938.
Charge storage dissector. 2,140,695. December 20, 1938.
Controlling electron multipliers. 2,140,832. December 20, 1938.
Charge storage dissector tube. 2,141,836. December 27, 1938.
Multistage multipactor. 2,141,837. December 27, 1938.
Split cathode multiplier tube. 2,141,838. December 27, 1938.
Projection means. 2,143,145. January 10, 1939.
Repeater. 2,143,146. January 10, 1939. [With R. L. Snyder.]
Electron multiplication. 2,143,262. January 10, 1939.
Cathode ray tube. 2,149,045. February 28, 1939.
Dissector tube. 2,153,918. April 11, 1939.
Producing incandescent images. 2,155,478. April 25, 1939. [With H. S. Bamford.]
Means and method for transmitting synchronizing pulses in television. 2,155,479. April 25, 1939.
Cathode ray tube. 2,158,279. May 16, 1939.
Absorption oscillator. 2,159,521. May 23, 1939.
Two-stage electron multiplier. 2,161,620. June 6, 1939.
Television method. 2,168,768. August 8, 1939.
Radio frequency multipactor amplifier. 2,172,152. September 5, 1939.
Self-energized alternating current multiplier. 2,174,487. September 26, 1939.
Oscillator. 2,174,488. September 26, 1939.
Producing an incandescent image. 2,179,086. November 7, 1939.
Electron multiplier. 2,179,996. November 14, 1939.
Operating electron multipliers. 2,180,279. November 14, 1939.
Cold cathode electron discharge tube. 2,184,910. December 26, 1939.
Diode oscillator tube construction. 2,189,358. February 6, 1940.
Shielded anode electron multiplier. 2,203,048. June 4, 1940. [With R. L. Snyder.]
Producing electron multiplication. 2,204,479. June 11, 1940.
Image dissector. Reissue 21,504. July 9, 1940.
Two-stage oscillograph. 2,216,266. October 1, 1940.
Split cathode multiplier. 2,217,860. October 15, 1940.
Image source. 2,213,070. August 27, 1940.
Scanning current generator. 2,214,077.
Means and method of image analysis. 2,216,264. October 1, 1940.
Image dissector. 2,216,265. October 1, 1940.
X-ray projection device. 2,221,374. November 12, 1940.
Amplifier. 2,221,473. November 12, 1940.
High efficiency amplifier. 2,223,001. November 26, 1940.
Cathode ray amplifier. 2,228,388. January 14, 1941.
Image projector. 2,233,887. March 4, 1941.
Charge storage amplifier. 2,233,888. March 4, 1941.
Dissector tube. 2,235,477. March 18, 1941.
Electronic amplifier. 2,239,149. April 22, 1941.
Television scanning and synchronizing system. 2,246,625. June 24, 1941.
Cathode ray amplifying tube. 2,251,124. July 29, 1941.
Image analyzing system. 2,254,140. August 26, 1941.
Image amplifier. 2,257,942. October 7, 1941.

Farnsworth, cont.

Electron multiplier. 2,260,613. October 28, 1941.
Cold cathode electron discharge tube. 2,263,032. November 18, 1941.
Dissector tube. 2,264,630. December 2, 1941.
Electron image amplifier. Reissue 22,009. January 20, 1942.
Apparatus for and electron discharge control. 2,274,194. February 24, 1942.
Scanning means and method. 2,280,572. April 21, 1942.
Electron control device. 2,286,076. June 9, 1942.
Manufacturing cathode-ray targets. 2,286,478. June 16, 1942.
Rectifier. 2,287,607. June 23, 1942.
Image amplifier. 2,291,577. July 28, 1942.
Image dissector. 2,292,111. August 4, 1942.
Electron image amplifier. 2,292,437. August 11, 1942.
Deflecting system. 2,297,949. October 6, 1942.
Cathode ray signal reproducing tube. 2,301,388. November 10, 1942.
Electric recording and reproducing system. 2,304,633. December 8, 1942.
Electron control device. 2,311,981. February 23, 1943.
Television projection system. 2,315,113. March 30, 1943.
Image reproducing device. 2,355,212. August 8, 1944.
Television image analyzing tube. 2,641,723. June 9, 1953.
Cathode ray tube and system. 2,754,449. July 10, 1956.
Storage type electron tube systems. 2,830,111. April 8, 1958.
Color television apparatus. 2,921,228. January 12, 1960.
Cathode ray tube. 2,941,100. June 14, 1960.
Color television receiver. 2,951,113. August 30, 1960.
Light translating device. 2,992,346. July 11, 1961.
Radiation translating device. 2,992,358. July 11, 1961.
Electron image-discharge device. 3,108,202. October 22, 1963.
Transducing apparatus. 3,073,899. January 15, 1963.
Ion transport vacuum pump. 3,181,028. April 27, 1965.
Electron gun in the form of a multipactor. 3,201,640. August 17, 1965.
Ion transport pump. 3,240,421. March 15, 1966.
Electric discharge device for producing interactions between nuclei. 3,258,402. June 28, 1966.
Process and apparatus for drying and treating lumber. 3,283,412. Nov. 8, 1966.
Microwave amplifier utilizing multipaction to produce periodically bunched electrons. 3,312,857. April 4, 1967.
Method and apparatus for producing nuclear-fusion reactions. 3,386,883. June 4, 1968.
Lumber drying. 3,574,949. April 13, 1971. [With Frederick R. Furth.]

Patents In Alphabetical Order

[See previous pages for complete citations.]

Absorption oscillator. 2,159,521.
Admittance neutralizing amplifier. 1,986,331.
Amplifier. 2,221,473.
Apparatus for and electron discharge control. 2,274,194.

Farnsworth, cont.
Two-stage oscillograph. 2,216,266.
X-ray projection device. 2,221,374.

REGINALD A. FESSENDEN (1866-1932)
Patents In Chronological (Patent Number) Order

Leading-in wire for incandescent lamps. 452,494. May 19, 1891. 55:912.
Manufacture of incandescent electric lamps. 453,742. June 9, 1891. 55:1324.
Molding for electrical conductors. 506,311. October 10, 1893. 65:179.
Pencil for incandescent lamps. 638,837. December 12, 1899. 89:2123. [With G. McCargo.]
Pencil for incandescent lamps. 638,838. Dec. 12, 1899. 89:2123. [With G. McCargo.]
Incandescent lamp. 638,839. Dec. 12, 1899. 89:2123. [With G. McCargo.]
Incandescent lamp. 638,840. December 12, 1899. 89:2123. [With G. McCargo.]
Incandescent lamp. 639,161. December 12, 1899. 89:2231. [With G. McCargo.]
Induction-coil for X-ray apparatus. 644,972. March 6, 1900. 90:1907.
X-ray apparatus. 648,660. May 1, 1900. 91:933.
Incandescent lamp. 650,531. May 29, 1900. 91:1684. [With G. McCargo.]
Induction-coil. 654,390. July 24, 1900. 92:708.
Incandescent lamp. 670,316. March 19, 1901. 94:2306.
Wireless telegraphy. 706,735. August 12, 1902. 100:1420.
Apparatus for wireless telegraphy. 706,736. August 12, 1902. 100:1421.
Wireless telegraphy. 706,737. August 12, 1902. 100:1422.
Wireless telegraphy. 706,738. August 12, 1902. 100:1423.
Conductor for wireless telegraphy. 706,739. August 12, 1902. 100:1423.
Wireless signaling. 706,740. August 12, 1902. 100:1424.
Apparatus for wireless telegraphy. 706,741. August 12, 1902. 100:1424.
Wireless signaling. 706,742. August 12, 1902. 100:1425.
Wireless signaling. 706,743. August 12, 1902. 100:1426.
Current-actuated wave-responsive device. 706,744. August 12, 1902. 100:1426.
Signaling by electromagnetic waves. 706,745. August 12, 1902. 100:1426.
Signaling by electromagnetic waves. 706,746. August 12, 1902. 100:1427.
Apparatus for signaling by electromagnetic waves. 706,747. Aug. 12, 1902. 100:1428.
Current-operated receiver for electromagnetic waves. 715,043. Dec. 2, 1902. 101:1990.
Selective signaling by electromagnetic waves. 715,203. Dec. 2, 1902. 101:2053.
Transmission and receipt of signals. 727,325. May 5, 1903. 104:203.
Selective signaling by electromagnetic waves. 727,326. May 5, 1903. 104:204.
Receiver for electromagnetic waves. 727,327. May 5, 1903. 104:205.
Receiver for signaling. 727,328. May 5, 1903. 104:205.
Signaling by electromagnetic waves. 727,329. May 5, 1903. 104:205.
Signaling by electromagnetic waves. 727,330. May 5, 1903. 104:206.
Receiver for electromagnetic waves. 727,331. May 5, 1903. 104:206.
Receiver for electromagnetic waves. (Reissue) 12,115. May 26, 1903. 104:1108.
Signaling by electromagnetic waves. 730,753. June 9, 1903. 104:1606.
Utilizing the energy of waves. 731,029. June 16, 1903. 104:1734.
Signaling by electromagnetic waves. 742,779. October 27, 1903. 106:2260.

Fessenden, cont.

Signaling by electromagnetic waves. 742,780. October 27, 1903. 106:2260.
Wireless telegraphy. (Reissue) 12,168. Nov. 10, 1903. 107:529. [With D. S. Wolcott.]
Wireless telegraphy. (Reissue) 12,169. November 10, 1903. 107:530.
Selective signaling. 752,894. February 23, 1904. 108:1895.
Signaling by electromagnetic waves. 752,895. February 23, 1904. 108:1985.
Wireless signaling. 753,863. March 8, 1904. 109:300.
Signaling by electromagnetic waves. 753,864. March 8, 1904. 109:301.
Signaling by electromagnetic waves. 754,058. March 8, 1904. 109:385.
Apparatus for transmitting and receiving signals. 777,014. Dec. 6, 1904. 113:1672.
Capacity. 793,647. July 4, 1905. 117:9.
Receiver for electromagnetic waves. 793,648. July 4, 1905. 117:9.
Signaling by electromagnetic waves. 793,649. July 4, 1905. 117:10.
Signaling by electromagnetic waves. 793,650. July 4, 1905. 117:11.
Aerial for wireless signaling. 793,651. July 4, 1905. 117:11.
Signaling by electromagnetic waves. 793,652. July 4, 1905. 117:11.
Wireless telegraphy. 793,718. July 4, 1905. 117:40.
Condenser. 793,777. July 4, 1905. 117:68.
Capacity. 814,951. March 13, 1906. 121:467.
Wireless telegraphy. 897,278. September 1, 1908. 136:7.
Means for generating high-frequency electric oscillations. 897,279. Sept. 1, 1908. 136:7.
Electric signaling. 915,280. March 16, 1909. 140:586.
Signaling. 916,428. March 30, 1909. 140:1017.
Receiver for electromagnetic waves. 916,429. March 30, 1909. 140:1018.
Detecting device for wireless telegraphy. 917,574. April 6, 1909. 141:209.
Wireless signaling. 918,306. April 13, 1909. 141:484.
Apparatus for wireless signaling. 918,307. April 13, 1909. 141:484.
Receiver for electromagnetic waves. 921,531. May 11, 1909. 142:506.
Wireless telegraphy. 923,962. June 8, 1909. 143:318.
Wireless telegraphy. 923,963. June 8, 1909. 143:318.
Signaling by electromagnetic waves. 928,371. July 20, 1909. 144:617.
Producing high-frequency oscillations. 932,111. August 24, 1909. 145:902.
Lightning-arrester. 932,112. August 24, 1909. 145:902.
Means for cleaning guns. 938,836. November 2, 1909. 148:133.
Determining positions of vessels. 941,565. November 30, 1909. 148:1163.
Wireless telegraphy. 948,068. February 1, 1910. 151:98.
Signaling by electromagnetic waves. 956,489. April 26, 1910. 153:1054.
Wireless signaling. 960,631. June 7, 1910. 155:132.
Electric signaling. 962,014. June 21, 1910. 155:648.
Receiver for electric signaling. 962,015. June 21, 1910. 155:648.
Receiver for electromagnetic waves. 962,016. June 21, 1910. 155:649.
Electrical apparatus. 962,017. June 21, 1910. 155:649.
Method of signaling. 962,018. June 21, 1910. 155:649.
Wireless telegraphy. 974,762. November 1, 1910. 160:238.
Transmission and receipt of electrical energy. 979,144. Dec. 20, 1910. 161:651.
Electrical signaling. 979,145. December 20, 1910. 161:652.
Multiplex telegraphy. 981,406. January 10, 1911. 162:456.
Signaling by electromagnetic waves. 998,567. July 18, 1911. 168:754.

Fessenden, cont.

Signaling by electromagnetic waves. 1,002,049. August 29, 1911. 169:1102.
Receiver for signaling. 1,002,050. August 29, 1911. 169:1103.
Signaling by electromagnetic waves. 1,002,051. August 29, 1911. 69:1103.
Electrical signaling. 1,002,052. August 29, 1911. 169:1103.
Determining position of vessels. 1,002,141. August 29, 1911. 169:1132.
Means for transmission of energy by electromagnetic waves. 1,015,881. January 30, 1912. 174:1070.
Signaling. 1,019,236. March 5, 1912. 176:80.
Signaling by electromagnetic waves. 1,020,032. March 12, 1912. 176:376.
Receiver for electromagnetic waves. 1,022,539. April 9, 1912. 177:294.
Wireless signaling. 1,022,540. April 9, 1912. 177:294.
Determining frequency of periodic impulses. 1,022,584. April 9, 1912. 177:309.
Wireless telegraphy. 1,035,334. August 13, 1912. 181:345.
High-frequency electrical conductor. 1,039,717. October 1, 1912. 183:16.
Receiver for electromagnetic waves. 1,042,778. October 29, 1912. 183:1182.
Receiving electromagnetic waves. 1,044,637. November 19, 1912. 184:615.
Wireless telegraphy. 1,045,781. November 26, 1912. 184:1045.
Wireless telegraphy. 1,045,782. November 26, 1912. 184:1045.
Contact for electromagnetic mechanism. 1,048,670. December 31, 1912. 185:1131. [With H. M. Barrett.]
Electric signaling apparatus. 1,050,441. January 14, 1913. 186:417. [Note 1.]
Signaling. 1,050,728. January 14, 1913. 186:512. [Note 1.]
Wireless telegraphy. 1,059,665. April 22, 1913. 189:898. [Note 1.]
Apparatus for wireless signaling. 1,059,666. April 22, 1913. 189:898. [Note 1.]
Wireless signaling. 1,074,423. September 30, 1913. 194:1064.
Magnetic material. 1,074,424. September 30, 1913. 194:1064. [Note 1.]
Signaling by electromagnetic waves. 1,080,271. Dec. 2, 1913. 197:124. [Note 1.]
Apparatus for electric signaling. 1,101,914. June 30, 1914. 203:1404. [Note 1.]
Wireless signaling. 1,101,915. June 30, 1914. 203:1405. [Note 1.]
Signaling by sound and other longitudinal elastic impulses. 1,108,895. September 1, 1914. 206:11.
System of storing power. 1,112,441. October 6, 1914. 207:9.
Storage and care of wheeled vehicles. 1,114,975. October 27, 1914. 207:1033.
Agricultural engineering. 1,121,722. December 22, 1914. 209:1102.
Sending mechanism for electromagnetic waves. 1,126,966. February 2, 1915. 211:105. [Note 1.]
Apparatus for converting heat into work. 1,132,465. March 16, 1915. 212:992.
Electric signaling. 1,132,568. March 23, 1915. 212:1077. [Note 1.]
Wireless telegraphy. 1,132,569. March 23, 1915. 212:1077. [Note 1.]
Method of and apparatus for reproducing impulses. 1,133,435. March 30, 1915. 212:1428.
Transmitting and receiving electrical energy. 1,141,386. June 1, 1915. 215:108. [Note 1.]
Apparatus for the transmission and receipt of electrical energy. 1,141,453. June 1, 1915. 215:131. [Note 1.]
Wireless telegraphy. 1,147,010. July 20, 1915. 216:753. [Note 1.]
Amplifying electrical impulses. 1,154,750. September 28, 1915. 218:936.

Fessenden, cont.

Apparatus for the transmission of energy by electric oscillations. 1,156,677. October 12, 1915. 219:497. [Note 1.]

Transmitting and receiving signals. 1,157,094. Oct. 19, 1915. 219:673. [Note 1.]

Apparatus for generating and receiving electromagnetic waves. 1,158,123. October 26, 1915. 219:1097. [Note 1.]

Signaling apparatus for aerial navigation. 1,158,124. Oct. 26, 1915. 219:1097. [Note 1.]

Apparatus for wireless signaling. 1,165,862. Dec. 28, 1915. 221:1217. [Note 1.]

Apparatus for producing high-frequency oscillations. 1,166,892. January 4, 1916. 222:167. [Note 1.]

Producing high-frequency oscillations. 1,166,893. January 4, 1916. 222:168.

Dynamo-electric machinery. 1,167,366. January 4, 1916. 222:334.

Means of transmitting intelligence. 1,170,969. Feb. 8, 1916. 223:458. [Note 1.]

Transmitting energy by electromagnetic waves. 1,172,017. Feb. 15, 1916. 223:875. [Note 1.]

Electromagnetic indicator. 1,172,018. February 15, 1916. 223:875. [Note 1.]

Wireless telegraphy. 1,175,418. March 14, 1916. 224:530. [Note 1.]

Wireless signaling. 1,176,282. March 21, 1916. 224:872. [Note 1.]

Wireless signaling. 1,178,507. April 11, 1916. 225:385. [Note 1.]

Electric signaling. 1,179,906. April 18, 1916. 225:932. [Note 1.]

Signaling by electromagnetic waves. 1,182,003. May 9, 1916. 226:353. [Note 1.]

Signaling. 1,182,843. May 9, 1916. 226:646.

Signaling by electromagnetic waves. 1,184,843. May 30, 1916. 226:1485.

Utilizing pulverulent matter as fuel. 1,191,072. July 11, 1916. 228:701.

Method and apparatus for amplifying electric impulses. 1,196,938. September 5, 1916. 230:72. [With L. Cohen, S. M. Kintner, and H. M. Barrett.]

Apparatus and method for producing vibratory motions. 1,207,387. Dec. 5, 1916. 233:208.

Method and apparatus for submarine signaling. 1,207,388. Dec. 5, 1916. 233:208.

Submarine, subterranean, and aerial telephony. 1,212,202. Jan. 16, 1917. 234:690.

Apparatus for phonograph-kinetoscopes. 1,213,176. January 23, 1917. 234:1067.

Dynamo-electric machinery. 1,213,610. January 23, 1917. 234:1219.

Dynamo-electric machinery. 1,213,611. January 23, 1917. 234:1219

Power generation. 1,214,531. February 6, 1917. 235:17.

Power plant. 1,217,165. February 27, 1917. 235:1072.

Measuring distance. 1,217,585. February 27, 1917. 235:1220.

Method and apparatus for locating ore-bodies. 1,240,328. Sep. 18, 1917. 242:576.

System of storing power. 1,247,520. November 20, 1917. 244:768.

Method and apparatus for producing alternating currents. 1,265,068. May 7, 1918. 250:55.

Gun-sight. 1,265,766. May 14, 1918. 250:275.

Method and apparatus for agricultural engineering. 1,268,949. June 11, 1918. 251:266.

Method and apparatus for transmitting and receiving sound-waves through ground. 1,270,398. June 25, 1918. 251:721.

Sound-producer. 1,277,562. September 3, 1918. 254:63.

Apparatus for submarines. 1,291,458. January 14, 1919. 258:368.

Method of and apparatus for heat insulation. 1,301,675. April 22, 1919. 261:751.

Fessenden, cont.

Submarine signaling. 1,311,157. July 29, 1919. 264:710.

Submarine signaling. 1,318,739. October 14, 1919. 267:267.

Method of and apparatus for obtaining increased circulation. 1,318,740. October 14, 1919. 267:267.

Detecting and locating ships. 1,319,145. October 21, 1919. 267:371.

Method and apparatus for eliminating undesired vibrations. 1,319,521. October 21, 1919. 267:442.

Method and apparatus for cooling and lubricating systems. 1,331,907. February 24, 1920. 271:601.

Locating enemy-gun positions. 1,341,795. June 1, 1920. 275:36.

Apparatus for submarine signaling. 1,348,556. August 3, 1920. 277:83.

Method and apparatus for detecting low-frequency impulses. 1,348,825. August 3, 1920. 277:133.

Method and apparatus for submarine signaling and detection. 1,348,826. Aug. 3, 1920. 277:133.

Method and apparatus for submarine signaling. 1,348,827. Aug. 3, 1920. 277:133.

Method and apparatus for sound insulation. 1,348,828. August 3, 1920. 277:134.

Method and apparatus for locating submarines. 1,348,855. Aug. 10, 1920. 277:192.

Apparatus for directive signaling. 1,348,856. Aug. 10, 1920. 277:192.

Apparatus for directive signaling. 1,355,598. October 12, 1920. 279:279.

Artificial-leather article. 1,357,449. November 2, 1920. 280:47.

Wheel-puller. 1,357,698. November 2, 1920. 280:94.

Wireless direction-finder. 1,374,293. April 12, 1921. 285:218.

Destroying enemy gun positions. 1,383,219. June 28, 1921. 287:711.

Method and apparatus for signaling and otherwise utilizing radiant impulses. 1,384,014. July 5, 1921. 288:157.

Sound signaling. 1,384,029. July 5, 1921. 288:160.

Destroying enemy gun positions. 1,384,030. July 5, 1921. 288:160.

Submarine signaling. 1,394,482. October 18, 1921.

Method and apparatus for submarine signaling. 1,394,483. October 18, 1921.

Method and apparatus for submarine signaling. 1,397,949. November 22, 1921.

Stop-clock. 1,397,950. November 22, 1921.

Method and apparatus for inspecting materials. 1,414,077. April 25, 1922.

Method and apparatus for submarine signaling. 1,415,539. May 9, 1922.

Method and apparatus for detecting, measuring, and utilizing low-frequency impulses. 1,429,497. September 19, 1922.

Acoustic method and apparatus. 1,453,316. May 1, 1923.

Directional receiving of submarine signals. 1,472,558. October 30, 1923.

Eliminating undesired impulses. 1,473,179. November 6, 1923.

Apparatus for producing and receiving signals. 1,486,735. March 11, 1924.

Method and apparatus for signaling. 1,497,366. June 10, 1924.

Submarine signaling. 1,501,105. July 15, 1924.

Eliminating disturbing energy. 1,534,205. April 21, 1925.

Apparatus for amplifying. 1,546,440. July 21, 1925.

Eliminating disturbing noises. 1,547,740. July 28, 1925.

Method and apparatus for generating electrical oscillations. 1,553,152. Sep. 8, 1925.

Apparatus for directive signaling. 1,561,441. November 10, 1925.

Signaling by ultra-audible sound waves. 1,562,950. November 24, 1925.
Channel pilot. 1,574,074. February 23, 1926.
Infusor. 1,576,735. March 16, 1926.
Acoustic method and apparatus. (Reissue) 16,372. June 29, 1926.
Method and apparatus for coordinating radio and phonograph reproduction. 1,616,416. February 1, 1927.
Book reproducible by radiant energy. 1,616,848. February 8, 1927.
Wireless directive signaling. 1,617,240. February 8, 1927.
Method and apparatus for the transmission of energy by high-frequency impulses. 1,617,241. February 8, 1927.
Wireless transmission and reception. 1,617,242. February 8, 1927.
Method and apparatus for determining distance by echo. 1,636,502. July 19, 1927.
Method and apparatus for producing and reading books. 1,732,302. Oct. 22, 1929.
Method and apparatus for heating buildings. 1,802,970. April 28, 1931.
Method and apparatus for determining distance by echo. 1,853,119. April 12, 1932.
Method and apparatus for generating and detecting impulses. 1,854,025. April 12, 1932.
Apparatus for setting to best photographic exposure. 1,859,621. May 24, 1932.
Loud speaker apparatus and method. 1,863,840. June 21, 1932.
Method and apparatus for coordinating radio and phonograph reproduction. 1,863,841. June 21, 1932.
Parking cars. 1,882,183. October 11, 1932.
Modulating electrical energy by light impulses. 1,899,026. February 28, 1933.
Light modulators and constructing the same. 1,901,502. March 14, 1933.
Rotary brush. 1,901,503. March 14, 1933.
Height indicator. 1,924,032. August 22, 1933.
Method and apparatus for sound transmission. 1,965,226. July 3, 1934.
Height indicator. 1,991,892. February 19, 1935.
Television system. 2,059,221. November 3, 1936. [Issued in name of Fessenden, Reginald A., deceased and H. M. Fessenden, executrix .]
Television apparatus. 2,059,222. November 3, 1936. [Issued in name of Fessenden, Reginald A., deceased and H. M. Fessenden, executrix .]

[Note 1: With S. M. Kintner and H. M. Barrett.]

Patents In Alphabetical Order

[See previous pages for complete citations.]

Acoustic method and apparatus. 1,453,316.
Acoustic method and apparatus. Reissue 16,372. June 29, 1926.
Aerial for wireless signaling. 793,651.
Agricultural engineering. 1,121,722.
Amplifying electrical impulses. 1,154,750.
Apparatus and method for producing vibratory motions. 1,207,387.
Apparatus for amplifying. 1,546,440.
Apparatus for converting heat into work. 1,132,465.
Apparatus for directive signaling. 1,348,856; 1,355,598; 1,561,441.

Fessenden, cont.

Fessenden, cont.

Fessenden, cont.

Wireless transmission and reception. 1,617,242.

X-ray apparatus. 648,660.

JOHN A. FLEMING (1849-1945)

Patents In Chronological (Patent Number) Order

Preparation of materials for use in electric insulation. 259,271. June 6, 1882. 21:1777.

Preparation of insulating materials or articles. 284,289. Sept. 4, 1883. 24:931.

Preparation of insulating materials or articles. 319,084. June 2, 1885. 31:1083.

Electric-arc lamp. 653,572. July 10, 1900. 92:331.

Device for wireless telegraphy. 758,004. April 19, 1904. 109:2140.

Apparatus employed in wireless telegraphy. 758,005. April 19, 1904. 109:2141.

Transmitter apparatus for wireless telegraphy. 792,014. June 13, 1905. 116:1747.

Telegraphic signaling-key. 792,015. June 13, 1905. 116:1748.

Instrument for converting alternating electric currents into continuous currents. 803,684. Nov. 7, 1905. 119:72.

Apparatus for measuring the length of electric waves 804,189. Nov. 7, 1905. 119:293.

Instrument for making electrical measurements. 804,190. Nov. 7, 1905. 119:294.

Instrument for detecting electric oscillations. 954,619. April 12, 1910. 153:349.

Thermionic device. 1,486,237. March 11, 1924.

Fleming Patents In Alphabetical Order

[See previous page for complete citations.]

Apparatus employed in wireless telegraphy. 758,005.

Apparatus for measuring the length of electric waves. 804,189.

Device for wireless telegraphy. 758,004.

Electric-arc lamp. 653,572.

Instrument for converting alternating electric currents into continuous currents. 803,684.

Instrument for detecting electric oscillations. 954,619.

Instrument for making electrical measurements. 804,190.

Preparation and production of insulating materials or articles. 319,084.

Preparation of materials for use in electric insulation. 259,271.

Preparation or production of insulating materials or articles. 284,289.

Telegraphic signaling-key. 792,015.

Thermionic device. 1,486,237.

Transmitter apparatus for wireless telegraphy. 792,014.

A. ATWATER KENT (1873-1949)

Patents In Chronological (Patent Number) Order

Electric toy. 671,891. April 9, 1901. 95:404. [With Kendrick and Davis.]

Electric measuring instrument. 764,814. July 12, 1904. 111:428.

Vibrator for induction or spark coils. 783,207. February 21, 1905. 114:2010.

Means for preventing strains and vibrations in power-transmission devices. 798,682. September 5, 1905. 118:59.

Kent, cont.

Governor. 838,256. December 11, 1906. 125:1892.
Measuring-gage. 922,152. May 18, 1909. 142:738.
Sparking device. 950,339. Feb. 22, 1910. 151:951. [With Thomas H. McQuown.]
Electric contact device. 978,030. December 6, 1910. 161:209.
Massage-machine. 978,031. December 6, 1910. 161:210.
Signaling-horn. 1,001,046. August 22, 1911. 169:735.
Electric-circuit closer and breaker. 1,011,070. December 5, 1911. 173:232. [With Thomas H. McQuown.]
Electric meter. 1,019,163. March 5, 1912. 176:55.
Combined switch and starting device. 1,043,110. November 5, 1912. 184:21.
Electric device. 1,082,810. December 30, 1913. 197:1119.
Device for uniting insulated conductors of electricity. 1,082,811. December 30, 1913. 197:1120.
Circuit-controller. 1,096,109. May 12, 1914. 202:354.
Electric contact device. 1,099,093. June 2, 1914. 203:246.
Electric-circuit closer and breaker. 1,109,689. September 8, 1914. 206:335.
Electric contact device. 1,152,642. September 7, 1915. 218:97.
Signaling-horn. 1,152,643. September 7, 1915. 218:97.
Switch. 1,184,183. May 23, 1916. 226:1212.
Electric contact device. 1,192,786. July 25, 1916. 228:1397.
Automatic spark-advancing mechanism. 1,192,787. July 25, 1916. 228:1397.
Electric igniting mechanism for internal-combustion engines. 1,192,788. July 25, 1916. 228:1398.
Horn. 1,222,107. April 10, 1917. 237:417.
Electric contact device. 1,246,818. November 13, 1917. 244:530.
Circuit make-and-break device. 1,255,846. February 12, 1918. 247:259. [With Walter D. Appel.]
Vehicle-spring. 1,288,915. December 24, 1918. 257:764.
Contact device. 1,289,036. December 24, 1918. 257:792.
Electric igniting mechanism for internal-combustion engines. 1,341,136. May 25, 1920. 274:672.
Condenser unit and making same. 1,351,787. September 7, 1920. 278:14. [With William H. Richter.]
Prismatic telescope. 1,364,381. January 4, 1921. 282:64.
Contact device. Reissue 15,128. June 21, 1921. 287:545.
Induction-coil-heat-dissipating structure. 1,385,624. July 26, 1921. 288:695.
Distributor structure. 1,385,625. July 26, 1921. 288:695.
Ignition timer structure. 1,385,626. July 26, 1921. 288:696.
Induction-coil structure. 1,391,256. September 20, 1921. 290:496.
Electric contact device. 1,395,427. November 1, 1921.
Ignition-control apparatus. 1,407,284. February 21, 1922.
Ignition-control apparatus. 1,407,466. February 21, 1922.
Vehicle seat. 1,417,744. May 30, 1922.
Rheostat. 1,445,324. February 13, 1923.
Engine-starting apparatus. 1,464,714. August 14, 1923.
Induction-coil. 1,474,152. November 13, 1923.
Induction coil. 1,474,597. November 20, 1923.

Kent, cont.

Ignition apparatus. 1,474,970. November 20, 1923.
Ignition apparatus. 1,476,522. December 4, 1923.
Ignition system for internal-combustion engines. 1,479,388. Jan. 1, 1924. [With W. A. Evans.]
Coupling and tuning apparatus. 1,485,931. March 4, 1924.
Variable-coil structure. 1,514,322. November 4, 1924.
Rheostat. 1,519,621. December 16, 1924.
Condenser and holder therefor. 1,520,027. December 23, 1924.
Variometer. 1,523,832. January 20, 1925.
Rheostat. 1,524,258. January 27, 1925.
Loud speaker. 1,534,267. April 21, 1925.
Ignition apparatus. 1,560,246. November 3, 1925.
Ignition apparatus. 1,560,247. November 3, 1925.
Ignition coil. 1,569,756. January 12, 1926.
Ignition apparatus. 1,570,680. January 26, 1926.
Electric igniting mechanism for internal-combustion engines. Reissue 16,313. April 6, 1926.
Panel condenser. 1,582,826. April 27, 1926.
Panel condenser. 1,583,071. May 4, 1926.
Panel condenser. 1,583,471. May 4, 1926.
Condenser. 1,588,474. June 15, 1926.
Electromagnetic switch. 1,591,133. July 6, 1926.
Ignition apparatus. 1,591,424. July 6, 1926.
Radio apparatus. 1,597,901. August 31, 1926.
Vacuum-tube unit. 1,650,754. November 29, 1927.
Method and apparatus for producing oscillations. 1,651,012. November 29, 1927. [With Thomas Appleby.]
Radiocabinet. Design 74,149. December 27, 1927.
Radio apparatus. 1,655,372. January 3, 1928.
Radio receiving apparatus. 1,658,562. February 7, 1928.
Adjustable resistance. 1,668,117. May 1, 1928.
Radio receiving apparatus. 1,668,155. May 1, 1928.
Condenser. 1,668,320. May 1, 1928.
Loud speaker. 1,673,461. June 12, 1928.
Detector apparatus. 1,679,310. July 31, 1928.
Control method and apparatus. 1,683,012. Sep. 4, 1928. [With Thomas Appleby.]
Cabinet for radio receiving apparatus. Design 76,812. November 6, 1928.
Cabinet for radio receiving apparatus. Design 78,030. March 19, 1929.
Radio speaker. 1,705,925. March 19, 1929.
Cabinet. 1,710,482. April 23, 1929.
Condenser. 1,713,134. May 14, 1929.
Radio apparatus. 1,719,014. July 2, 1929.
Transformer. 1,719,057. July 2, 1929.
Method of and apparatus for producing oscillations. 1,719,956. July 9, 1929. [With Thomas Appleby.]
Ignition-governing apparatus. 1,725,522. August 20, 1929.
Loudspeaker. 1,727,604. September 10, 1929.

Kent, cont.

Vacuum-tube holder. 1,730,010. October 1, 1929.
Radio loud-speaking apparatus. 1,743,145. January 14, 1930.
Loud-speaker mounting. 1,757,719. May 6, 1930.
Ignition-timing apparatus. 1,760,145. May 27, 1930
Receiving system. 1,775,399. September 9, 1930.
Cabinet for radio receiving apparatus. Design 82,206. September 30, 1930.
Cabinet for radio receiving apparatus. Design 82,207. September 30, 1930.
Radio receiving apparatus. 1,783,292. December 2, 1930.
Radio dial escutcheon plate. Design 83,046. January 13, 1931.
Radiospeaker. 1,794,855. March 3, 1931.
Volume control. 1,796,375. March 17, 1931.
Cabinet for radio receiving apparatus. Design 83,682. March 17, 1931.
Cabinet for radio receiving apparatus. Design 85,244. September 29, 1931.
Radio speaker. 1,829,007. October 27, 1931. [With R. T. Kingsford.]
Anode supply system. 1,972,279. September 4, 1934. [With Sarkes Tarzian.]
Reading apparatus. 2,325,324. July 27, 1943.

Patents In Alphabetical Order

[See previous pages for complete citations.]

Adjustable resistance. 1,668,117.
Anode supply system. 1,972,279.
Automatic spark-advancing mechanism. 1,192,787.
Cabinet. 1,710,482.
Cabinet for radio receiving apparatus. Design 76,812. November 6, 1928; Design 78,030. March 19, 1929; Design 82,206. September 30, 1930; Design 82,207. September 30, 1930; Design 83,682. March 17, 1931; Design 85,244. September 29, 1931.
Circuit-controller. 1,096,109.
Circuit make-and-break device. 1,255,846.
Combined switch and starting device. 1,043,110.
Condenser. 1,588,474; 1,668,320; 1,713,134.
Condenser and holder therefor. 1,520,027.
Condenser unit and making same. 1,351,787.
Contact device. 1,289,036.
Contact device. Reissue 15,128. June 21, 1921.
Control method and apparatus. 1,683,012.
Coupling and tuning apparatus. 1,485,931.
Detector apparatus. 1,679,310.
Device for uniting insulated conductors of electricity. 1,082,811.
Distributor structure. 1,385,625.
Electric-circuit closer and breaker. 1,011,070; 1,109,689.
Electric contact device. 978,030; 1,099,093; 1,152,642; 1,192,786; 1,246,818; 1,395,427.
Electric device. 1,082,810.
Electric igniting mechanism for internal-combustion engines. 1,192,788; 1,341,136. Reissue 16,313. April 6, 1926.

Kent, cont.

Electric measuring instrument. 764,814.
Electric meter. 1,019,163.
Electric toy. 671,891.
Electromagnetic switch. 1,591,133.
Engine-starting apparatus. 1,464,714.
Governor. 838,256.
Horn. 1,222,107.
Ignition apparatus. 1,474,970; 1,476,522; 1,560,246; 1,560,247; 1,570,680; 1,591,424.
Ignition coil. 1,569,756.
Ignition-control apparatus. 1,407,284; 1,407,466.
Ignition-governing apparatus. 1,725,522.
Ignition system for internal-combustion engines. 1,479,388.
Ignition timer structure. 1,385,626.
Ignition-timing apparatus. 1,760,145.
Induction coil. 1,474,152; 1,474,597.
Induction-coil-heat-dissipating structure. 1,385,624.
Induction-coil structure. 1,391,256.
Loud speaker. 1,534,267; 1,673,461; 1,727,604.
Loud-speaker mounting. 1,757,719.
Massage-machine. 978,031.
Means for preventing strains and vibrations in power-transmission devices. 798,682.
Measuring-gage. 922,152.
Method and apparatus for producing oscillations. 1,651,012.
Method of and apparatus for producing oscillations. 1,719,956.
Panel condenser. 1,582,826; 1,583,071; 1,583,471.
Prismatic telescope. 1,364,381.
Radio apparatus. 1,597,901; 1,655,372; 1,719,014.
Radio dial escutcheon plate. Design 83,046. January 13, 1931.
Radio loud-speaking apparatus. 1,743,145.
Radio receiving apparatus. 1,658,562; 1,668,155; 1,783,292.
Radio speaker. 1,705,925; 1,829,007.
Radiocabinet. Design 74,149. December 27, 1927.
Radiospeaker. 1,794,855.
Reading apparatus. 2,325,324.
Receiving system. 1,775,399.
Rheostat. 1,445,324; 1,519,621; 1,524,258.
Signaling-horn. 1,001,046; 1,152,643.
Sparking device. 950,339.
Switch. 1,184,183.
Transformer. 1,719,057.
Vacuum-tube holder. 1,730,010.
Vacuum-tube unit. 1,650,754.
Variable-coil structure. 1,514,322.
Variometer. 1,523,832.
Vehicle seat. 1,417,744.

Vehicle-spring. 1,288,915.
Vibrator for induction or spark coils. 783,207.
Volume control. 1,796,375.

GUGLIELMO MARCONI (1874-1937)

Patents In Chronological (Patent Number) Order

Transmitting electrical signals. 586,193. July 13, 1897. 80:222.
Apparatus employed in wireless telegraphy. 624,516. May 9, 1899. 87:926.
Apparatus employed in wireless telegraphy. 627,650. June 27, 1899. 87:2195.
Apparatus employed in wireless telegraphy. 647,007. April 10, 1900. 91:268.
Apparatus employed in wireless telegraphy. 647,008. April 10, 1900. 91:269.
Apparatus employed in wireless telegraphy. 647,009. April 10, 1900. 91:270.
Apparatus employed in wireless telegraphy. 650,109. May 22, 1900. 91:1515.
Apparatus employed in wireless telegraphy. 650,110. May 22, 1900. 91:1516.
Receiver for electrical oscillations. 668,315. February 19, 1901. 94:1454.
Transmitting electrical impulses and signals and apparatus therefor. Reissue 11,913. June 4, 1901. 95:2047.
Apparatus for wireless telegraphy. 676,332. June 11, 1901. 95:2257.
Wireless-telegraph system. 757,559. April 19, 1904. 109:1950.
Wireless signaling system. 760,463. May 24, 1904. 110:890.
Apparatus for wireless telegraphy. 763,772. June 28, 1904. 110:2423.
Wireless telegraphy. 786,132. March 28, 1905. 115:1006.
Wireless telegraphy. 792,528. June 13, 1905. 116:1954.
Wireless telegraphy. 884,986. April 14, 1908. 133:1647.
Wireless telegraphy. 884,987. April 14, 1908. 133:1647.
Detecting electrical oscillations. 884,988. April 14, 1908. 133:1648.
Wireless telegraphy. 884,989. April 14, 1908. 133:1648.
Receiver for wireless telegraphy. 896,130. August 18, 1908. 135:1383.
Wireless signaling system. 924,168. June 8, 1909. 143:384.
Wireless signaling system. 924,560. June 8, 1909. 143:513.
Transmitting apparatus for wireless telegraphy. 935,381. Sep. 28, 1909. 146:856.
Apparatus for wireless telegraphy. 935,382. September 28, 1909. 146:856.
Apparatus for wireless telegraphy. 935,383. September 28, 1909. 146:856.
Apparatus for wireless telegraphy. 954,640. April 12, 1910. 153:357.
Wireless telegraphy. 954,641. April 12, 1910. 153:357.
Transmitting apparatus for wireless telegraphy. 997,308. July 11, 1911. 168:274.
Means for generating alternating electric currents. 1,102,990. July 7, 1914. 204:265.
Duplex wireless telegraphy. 1,116,309. November 3, 1914. 208:286.
Transmitting apparatus for use in wireless telegraphy and telephony. 1,136,477. April 20, 1915. 213:931.
Transmitter for wireless telegraphy. 1,148,521. August 3, 1915. 217:13.
Transmitting apparatus for use in wireless telegraphy and telephony. 1,226,099. May 15, 1917. 238:777.
Transformer for high-frequency currents. 1,246,973. Nov. 20, 1917. 244:612.
Wireless-telegraph transmitter. 1,271,190. July 2, 1918. 252:124.

Marconi, cont.

Reflector for use in wireless telegraphy and telephony. 1,301,473. April 22, 1919. 261:713. [With C. S. Franklin.]

Electric accumulator. 1,377,722. May 10, 1921. 286:312.

Thermionic valve. 1,981,058. November 20, 1934. [With C. S. Franklin.]

Patents In Alphabetical Order

[See previous pages for complete citations.]

Apparatus for wireless telegraphy. 676,332; 763,772; 935,382; 935,383; 954,640.

Apparatus employed in wireless telegraphy. 624,516; 627,650; 647,007; 647,008; 647,009; 650,109; 650,110.

Detecting electrical oscillations. 884,988.

Duplex wireless telegraphy. 1,116,309.

Electric accumulator. 1,377,722.

Means for generating alternating electric currents. 1,102,990.

Receiver for electrical oscillations. 668,315.

Receiver for wireless telegraphy. 896,130.

Reflector for use in wireless telegraphy and telephony. 1,301,473.

Thermionic valve. 1,981,058.

Transformer for high-frequency currents. 1,246,973.

Transmitter for wireless telegraphy. 1,148,521.

Transmitting apparatus for use in wireless telegraphy and telephony. 1,136,477; 1,226,099.

Transmitting apparatus for wireless telegraphy. 935,381; 997,308.

Transmitting electrical impulses and signals and apparatus therefor. Reissue 11,913. June 4, 1901.

Transmitting electrical signals. 586,193.

Wireless signaling system. 760,463; 924,168; 924,560; 757,559.

Wireless-telegraph transmitter. 1,271,190.

Wireless telegraphy. 786,132; 792,528; 884,986; 884,987; 884,989; 954,641.

VLADIMIR ZWORYKIN (1889-1982)

Patents In Chronological (Patent Number) Order

Electric high-frequency signaling apparatus. 1,484,049. February 19, 1924.

Wireless transmitting system. 1,634,390. July 5, 1927.

Thermocouple. 1,643,734. September 27, 1927.

Cathode construction for thermionic devices. 1,657,986. January 31, 1928.

Photoelectric cell. 1,677,316. July 17, 1928.

Making resistance devices. 1,682,547. August 28, 1928.

Television system. 1,689,847. October 30, 1928.

Television system. 1,691,324. November 13, 1928.

Mercury-arc device. 1,696,023. December 18, 1928.

Variable light source. 1,709,647. April 16, 1929.

Interferometer microphone. 1,709,762. April 16, 1929.

Light-responsive relay. 1,709,763. April 16, 1929.

Television system. 1,715,732. June 4, 1929.

Pumping system for metal-tank rectifiers. 1,716,160. June 4, 1929. [With E. B. Shand.]

Zworykin, cont.

Photographic sound recording. 1,732,874. October 22, 1929.
Traffic supervisor. 1,743,175. January 14, 1930. [With Roy J. Wensley.]
Oscillator. 1,744,192. January 21, 1930.
Signaling system. 1,753,961. April 8, 1930.
Photoelectric device. 1,763,207. June 10, 1930.
Facsimile transmission system. 1,786,812. December 30, 1930.
Wireless picture transmission. 1,800,000. April 7, 1931.
System for recording electrical fluctuations. 1,802,747. April 28, 1931.
Light sensitive element. 1,807,056. May 26, 1931.
Television apparatus. 1,817,502. August 4, 1931.
Photographic printing apparatus. 1,826,858. October 13, 1931.
Photoelectric tube. 1,832,607. November 17, 1931.
Sound recording and reproducing system. 1,834,197. December 1, 1931.
Photoelectric tube. 1,837,744. December 22, 1931.
Vacuum tube. 1,837,745. December 22, 1931.
Photoelectric tube. 1,837,746. December 22, 1931.
Mercury arc device with grid control. 1,856,087. May 3, 1932. [With D. Ulrey.]
View transmission system. 1,863,363. June 14, 1932.
Frequency-responsive crystal relay. 1,869,829. Aug. 2, 1932. [With A. M. Skellett.]
Traffic supervisor. Reissue 18,567. August 9, 1932. [With Roy J. Wensley.]
Television apparatus. 1,870,702. August 9, 1932.
Photocell amplifier. 1,872,381. August 16, 1932. [With H. A. Iams.]
Combination of a phototube and an amplifier. 1,883,926. October 25, 1932. [With Harley Iams.]
Light sensitive tube. 1,893,573. January 10, 1933.
Facsimile receiver. 1,909,142. May 16, 1933.
Inspection device. 1,922,188. August 15, 1933.
Oscillation generator. 1,930,499. October 17, 1933.
Photoelectric tube. 1,939,531. December 12, 1933.
Kerr cell. 1,939,532. December 12, 1933.
Method and system for communication by television. 1,955,899. April 24, 1934.
Facsimile-transmission system. Reissue 19,314. September 11, 1934.
Sorting apparatus. 1,979,722. November 6, 1934.
Cathode ray apparatus. 1,988,469. January 22, 1935.
Recording system. 1,996,449. April 2, 1935.
Indicating device. 2,013,594. September 3, 1935.
Television system. 2,017,883. October 22, 1935.
Method of and apparatus for producing images of objects. 2,021,907. Nov. 26, 1935.
Television system. 2,022,450. November 26, 1935.
System for reception by television. 2,025,143. December 24, 1935.
Electrical communication system. 2,028,857. January 28, 1936.
Electric discharge device. 2,078,304. April 27, 1937.
Television system. 2,084,364. June 22, 1937.
Electrical device. 2,085,406. June 29, 1937.
Direction indicator. 2,103,507. December 28, 1937.
Television system. 2,104,066. January 4, 1938.
Television system. 2,107,464. February 8, 1938.

Zworykin, cont.

Vacuum tube. 2,109,245. February 22, 1938.
Ultrahigh frequency radio system. 2,125,977. August 9, 1938.
Television system. 2,133,882. October 18, 1938.
Cathode ray tube. 2,139,296. December 6, 1938.
Television system. 2,141,059. December 20, 1938.
Electron multiplier device. 2,144,239. January 17, 1939.
Intelligence transmission system. 2,146,876. February 14, 1939.
Electron multiplier device. 2,147,825. February 21, 1939.
Electric discharge device. 2,150,573. March 14,1939. [With L. Malter.]
Television system. 2,157,048. May 2, 1939.
Electric discharge device. 2,157,585. May 9, 1939.
Method and apparatus for detecting heat. 2,159,755. May 23, 1939.
Electrical device. 2,159,937. May 23, 1939.
Cathode ray device. 2,168,892. August 8, 1939.
High-frequency oscillator. 2,173,193. September 19, 1939.
Television system. 2,178,093. October 31, 1939. [With G. N. Ogloblinsky.]
Radio course indicator. 2,183,634. December 19, 1939.
Electric discharge device. 2,189,305. February 6, 1940.
Picture transmitter tube. 2,201,215. May 21, 1940.
Electric discharge device. 2,205,055. June 18, 1940. [With L. Malter.]
Television system. 2,206,654. July 2, 1940
Electron multiplier. 2,231,697. February 11, 1941. [With R. L. Snyder, Jr.]
Electron multiplier. 2,231,698. February 11, 1941. [With J. A. Rajchman.]
Secondary electron emissive electrode. 2,233,276. February 25, 1941. [With H. W. Leverenz and J. E. Ruedy.]
Photoelectric mosaic. 2,246,283. June 17, 1941.
Electron tube. 2,249,552. July 15, 1941.
Television system. 2,280,877. April 28, 1942.
Vacuum plumbing. 2,284,710. June 2, 1942.
View-transmission system. 2,285,551. June 9, 1942.
Electron gun. 2,289,952. July 14, 1942.
Power transmitting mechanism. 2,296,695. September 22, 1942.
Telelectroscope. 2,304,755. December 8, 1942.
View-transmission system. 2,338,562. January 4, 1944.
Dynamic method for correcting the spherical aberration of electron lenses. 2,354,287. July 25, 1944. [With E. G. Ramberg.]
Facsimile-transmission system. 2,361,255. October 24, 1944.
Television system. 2,415,059. January 28, 1947.
Convection current responsive instrument. 2,440,189. April 20, 1948.
Cathode-ray storage tube apparatus and method of operation. 2,451,005. October 12, 1948. [With Paul K. Weimer and I. Wolff.]
Optophone. 2,451,014. October 12, 1948. [With J. Hillier.]
Electronic reading aid for the blind. 2,457,099. Dec. 21, 1948. [With L. E. Flory.]
Color television. 2,566,713. September 4, 1951.
Apparatus for indicia recognition. 2,616,983. Nov. 4, 1952. [With L. E. Flory.]
Electronic simulator. 2,711,289. June 21, 1955.

Zworykin, cont.

Color television image reproduction. 2,725,420. November 29, 1955.

Secret television systems. 2,757,226. July 31, 1956.

Color television image reproducing systems. 2,806,899. September 17, 1957.

Automatic control system for vehicles. 2,847,080. August 12, 1958.

Color receiver utilizing velocity modulation in display tube. 2,989,582. June 20, 1961. [With J. A. Rajchman and E. G. Ramberg.]

Color kinescopes and methods of making the same. 3,003,873. Oct. 10, 1961.

Apparatus for meteorological exploration. 3,038,154. June 5, 1962.

Voltage sensing apparatus. 3,052,232. September 4, 1962. [With F. L. Hatke.]

Magnetic recording and reproducing means. 3,072,751. January 8, 1963. [With P. K. Weimer.]

Magnetic record reproducing apparatus. 3,213,206. October 19, 1965. [With P. K. Weimer.]

Photosensitive information retrieval device. 3,215,843. November 2, 1965.

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Wireless transmitting system. 1,634,390.

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David W. Kraeuter

David W. Kraeuter was born in Pittsburgh in 1941. He has been tinkering with and sometimes repairing electronic equipment since he was in grade school. Since 1985 his articles on the personal and whimsical side of radio history have appeared in Antique Radio Classified. In 1986 he became a founding member and officer of the Pittsburgh Antique Radio Society and has edited the Society's newsletter, The Pittsburgh Oscillator, since then. He is also the compiler of A Bibliography of Frank Conrad, which is available from the Society. He now plans to assemble a list of patents of the "second layer" of radio inventors if enough interest is shown. He has been a reference librarian at Washington and Jefferson College in Washington, PA, since earning a Master of Library Science degree from the University of Pittsburgh in 1968.