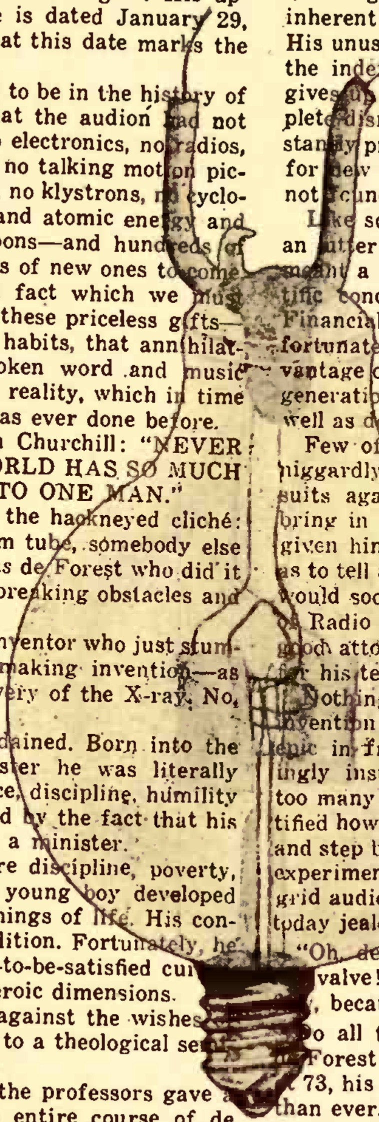
DE FOREST—FATHER OF RADIO

By Hugo Gernsback



THE year 1947 marks the 40th anniversary of the radio vacuum tube—Dr. Lee de Forest's three-element audion, the first grid radio tube. While de Forest invented other audions before 1907, these did not contain the all-important and vital grid. His application for patent of this tube is dated January 29, 1907, hence we can safely say that this date marks the birth of modern radio.

And what a milestone it proved to be in the history of radio! Imagine for a moment that the audion had not been invented: We would have no electronics, no radios, no broadcasting, no ocean phone, no talking motion pictures, no amplifiers, no television, no klystrons, no cyclotrons that made possible fission and atomic energy and its bombs, no guided radio weapons—and hundreds of other radio wonders, plus myriads of new ones to come.

It will always remain a vivid fact which we must never forget: de Forest gave us these priceless gifts—gifts that changed our lives, our habits, that annihilated distances, that made the spoken word and music through all space on this planet a reality, which in time will unite humanity as nothing has ever done before.

Verily—to paraphrase Winston Churchill: "NEVER IN THE HISTORY OF THE WORLD HAS SO MUCH BEEN OWED, BY SO MANY, TO ONE MAN."

The callous always will parrot the hackneyed cliché: "If *he* hadn't invented the vacuum tube, somebody else would have." Maybe so—but it *was* de Forest who did it first—and *how*, under what heartbreaking obstacles and disappointments!

De Forest never was a "lucky" inventor who just stumbled accidentally upon an epoch-making invention—as for instance Dr. Roentgen's discovery of the X-ray. No, he literally "sweated it out."

This, too, was seemingly preordained. Born into the parsonage of a poor Iowa minister he was literally steeped in such virtues as reverence, discipline, humility and thrift. All this was augmented by the fact that his mother, too, was the daughter of a minister.

Reared under the lash of severe discipline, poverty, and denial in the parsonage, the young boy developed a searing hunger for the better things of life. His constant dream was to better his condition. Fortunately, he was gifted not only with a never-to-be-satisfied curiosity, but with an imagination of heroic dimensions.

Thus we later find young Lee, against the wishes of his family, who wanted him to go to a theological seminary, enrolled at Yale University.

After the first semester one of the professors gave a lecture which was to change the entire course of de Forest's life. The lecture was on the electromagnetic wave theory with a demonstration of Heinrich Hertz's experiments. This caused a veritable flare-up in the young student who made this entry in his notebook:

"I shall learn all about the atom . . . shall guess its shape . . . shall postulate its causes and attractions . . . and I SHALL INVENT THE REASON FOR IT."

A bombastic promise—but it was more than fulfilled.

It has been my great pleasure to have known Lee de Forest since 1906—over forty years. I have come to know him very well, and I have had many opportunities to study him at close quarters over the years. I have been fortunate to have known Edison, Tesla, and other inventors equally well, and therefore believe myself qualified to judge the outstanding qualities of such men.

One cannot be long in de Forest's company before realizing that among his greatest characteristics is his inherent modesty. He speaks in measured, quiet phrases. His unusually deep-set eyes proclaim the man of science, the indefatigable worker, the type of man who never gives up a quest in search of light and truth. His complete disregard of his attire, his frugal living, his constantly preoccupied air, points to his tireless toil and zest for new worlds to conquer. Indeed at 73, he has as yet not found time to begin his autobiography.

Like so many men of the genius type, de Forest has an utter disregard for money. Finances have never meant a thing to him, except as a means to new scientific conquests, for research and for his inventions. Financial transactions bore him to distraction—and unfortunately for him the world has seen fit to take advantage of this: a pittance for his vacuum tube, his regeneration invention, his radiophone (broadcasting), as well as dozens of his more than two hundred inventions.

Few of history's great inventors have been paid so niggardly for epoch-making patents. Harassed by patent suits against him and countersuits which he had to bring in turn against others, the little money that was given him soon vanished. Once, because he was so rash as to tell a Federal court that with his radiophone a man would soon be able to talk across the ocean, the Father of Radio almost went to jail! If not for the pleas of a good attorney, de Forest would have been imprisoned for his temerity in predicting modern broadcasting!

Nothing ever came easy to the great inventor. The invention of the audion was no exception. It was an epic in frustration, in dogged plodding against seemingly insuperable, mountainous difficulties. There are too many witnesses who worked with him and who certified how he started with his Welsbach gas flame audion and step by step, through literally thousands of separate experiments, finally battled himself to the three-element grid audion. In spite of all this evidence, there are even today jealous, narrow-minded intolerants who say:

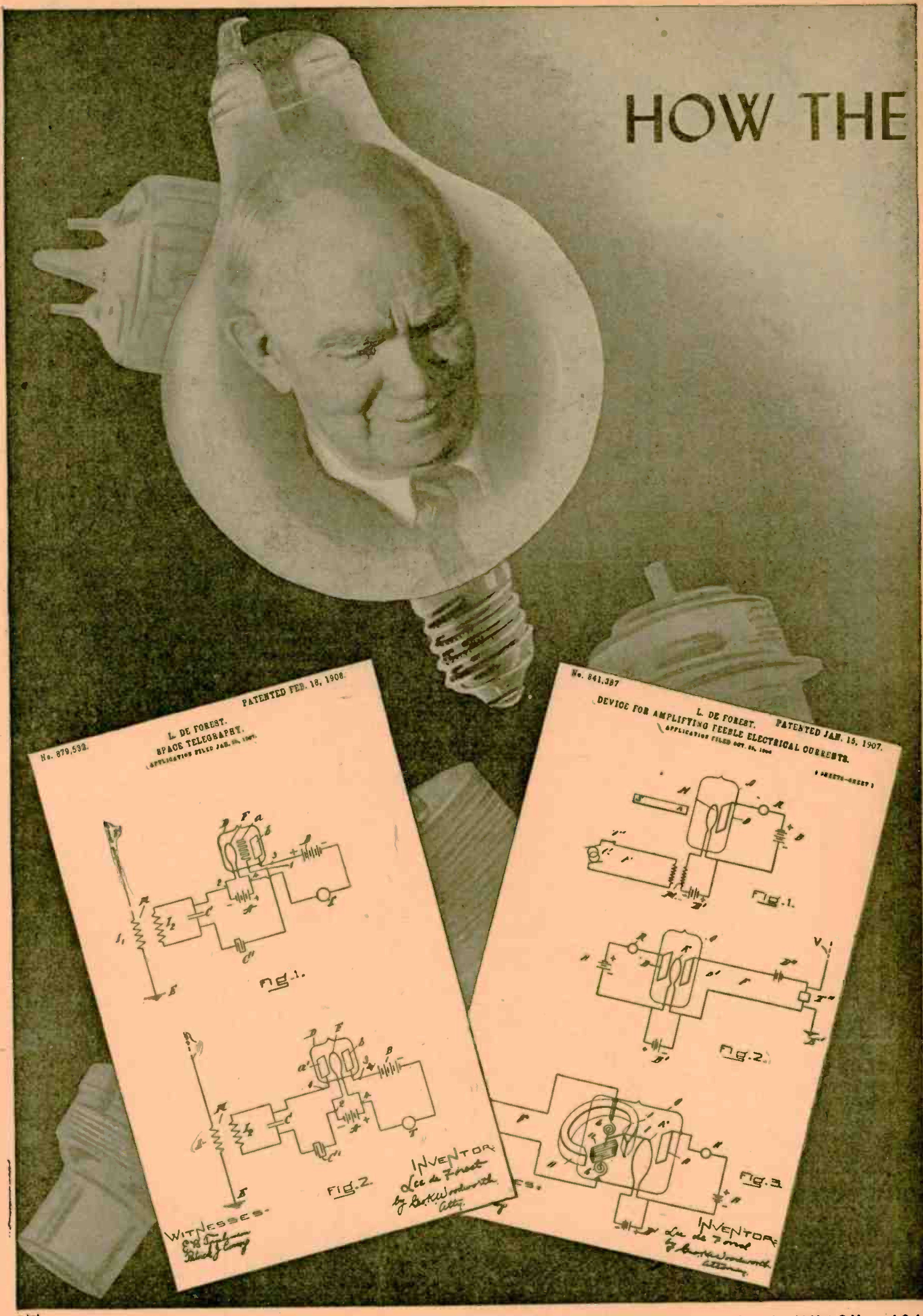
"Oh, de Forest, he just stuck a grid into the Fleming valve!" This is like saying: "The Wright brothers [illegible], because they stuck a propeller on an old kite."

Do all these soul-trying tribulations discourage Lee de Forest? Not in the least. His mind is as clear as ever at 73, his ideas as young as of yore, his curiosity keener than ever. The other day he and I discussed certain new aspects of a technical problem in television. For the first time during a two-hour conversation his deep-sunk eyes flashed and sparkled! His alert mind was stalking an idea once more!

This augurs well for his future. Let all of us—the entire radio-electronic fraternity—congratulate Dr. Lee de Forest on the 40th anniversary of his famed audion. Then let us wish him continuous good health, a long life, and many new laurels.

And, may I add, let the radio industry reward him financially for the staggering debt it owes the Father of Radio, which it can never hope to fully repay him.

HOW THE



No. 879,532.
PATENTED FEB. 18, 1908.
L. DE FOREST.
SPACE TELEGRAPHY.
Fig.1.
Fig.2.
WITNESSES:
INVENTOR:
Lee de Forest
No. 841,387.
L. DE FOREST.
PATENTED JAN. 15, 1907.
DEVICE FOR AMPLIFYING FEEBLE ELECTRICAL CURRENTS.
Fig.1.
Fig.2.
Fig.3
INVENTOR:

AUDION WAS INVENTED

Lee de Forest

IN THE summer of 1900, I was working under the light of a Welsbach gas burner in my hall bedroom in Chicago, experimenting with my so-called "Sponder," an anti-coherer for the reception of electrical waves for use in wireless telegraphy. One night I noticed that whenever the little spark from my transmitter coil was put in operation the light from the Welsbach burner dimmed. When my transmitter key was lifted, the normal light of the burner was restored. Thus I was able to translate into light variations the signals from my key. I was amazed and highly elated by this unexpected phenomenon, and for several weeks played with it, believing that I had accidentally discovered that incandescent gases were affected by Hertzian waves, and that here I had discovered an absolutely new principle which might be of the utmost value as a detector for wireless telegraphy. This illusion persisted until my assistant and I put the spark coil in a closet and closed the wooden door; thereupon the fluctuations of the gas burner were no longer observed. This proved conclusively that the effect observed was not due to the electrical waves from the spark, but to the sound waves therefrom. I had merely hit upon a new type of sensitive flame.

I was intensely disappointed by this outcome, but I was positive that there must be, nevertheless, some change in the conductivity of incandescent gases resulting from the passage therethrough of high-frequency electrical waves, and I determined to investigate further and prove that my original conception had a basis in the physics of gases.

Early Flame Detectors

It was not until 1903, when I was working in a small laboratory at 11 Thames Street, in lower Manhattan, that I had leisure and opportunity to resume my work in this direction. There I used a Bunsen burner, locating within the flame two platinum electrodes, one of which was connected through the telephone receiver to a dry battery, and thence to the other platinum electrode. I enriched the flame with sodium, or common salt.

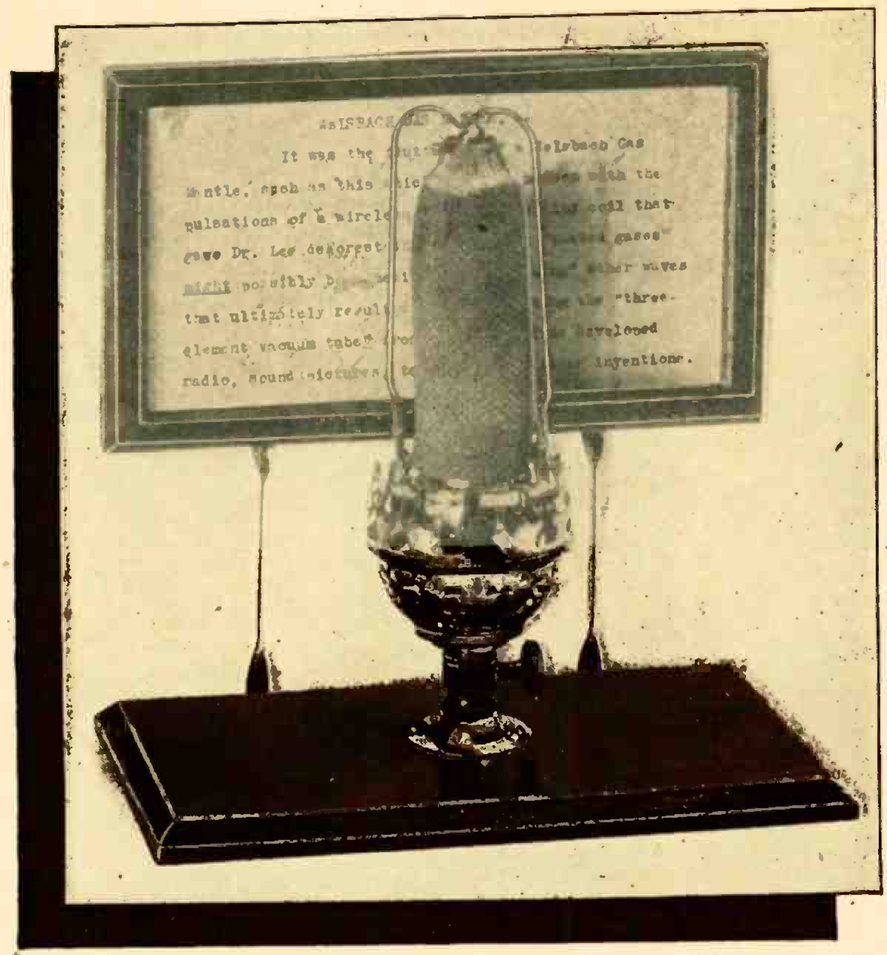
I then found that when the electrodes were properly located in the gas flame the signals from my spark transmitter were *distinctly audible* in the telephone receiver. I made countless experiments with this phenomenon; and to prove definitely that the effect was not acoustic but electrical, I connected one of the flame electrodes to my antenna, the other to the ground, and actually obtained wireless signals from ships in New York harbor.

Realizing that a gas-flame detector would be wholly unsuited for practical wireless work, I thought of other means for heating the gases. I tried a small electric arc—which was altogether too noisy to be of any use. After several futile attempts to build such a device myself, I persuaded Mr. McCandless, a manufacturer of miniature incandescent lamps, to build for me a tube containing a platinum plate and carbon filament. The plate was connected to the positive side of the dry battery; the negative terminal to the filament. In series was a telephone receiver. This device was *not* the Fleming valve. It has always been quite impossible for me to understand the confused idea, in the minds of some otherwise keen thinkers, that the audion differed from the Fleming valve merely by the insertion of a third electrode therein. *Without the use of the B-battery the valve would be nothing but a rectifier with one too many electrodes.* The employment of the local battery in the plate circuit is just as necessary an element to the success of the device as is the grid itself. At the time I was working on the two-element audion with B-battery, I had never heard of the Fleming valve. My approach to this perfected device was by an entirely different series of events, and began with the gas-flame detector.

Vacuum-Tube Detectors

This device was a genuine *relay*, in which the local energy of the plate battery supplying the current through the remaining gas in the tube was controlled by pulsations of the incoming high-frequency waves, which were picked up on an antenna connected to the plate electrode, the filament being connected to the ground. This was the same arrangement I had previously used with the gas flame detector. At that time I had requested McCandless not to exhaust the tube to any high degree of vacuum, because I then thought that the presence of gas was an essential element. This diode detector, as stated above, was intrinsically very much more than a simple rectifier of high-frequency current. The addition of the plate battery made a very great difference in the intensity of the signals received, for I was employing the high-frequency energy, not to actuate my telephone diaphragm, as Fleming had done, but to control very much larger quantities of energy from the local battery.

I argued that the above arrangement was imperfect because it permitted part of the high-frequency energy to pass to earth through the telephone and B-battery circuit, instead of concentrating it upon the ions between the plate and filament. To avoid this difficulty and still improve the sensitivity of the



Welsbach gas mantle, starting point of the series of experiments which led to the audion.

detector, I wrapped a piece of tin foil around the outside of the cylindrical-shaped gas envelope, and connected this third electrode to the antenna or to one terminal of the high-frequency device. I then realized that the efficiency could be still further enhanced if this third electrode were introduced within the envelope. I induced McCandless to construct another "audion," as I then called it. This last device contained two plates with a filament located between them, and, as before, a considerable amount of gas in the envelope. This detector showed further distinct improvement over its predecessors.

The Grid Audion

It occurred to me that the third, or control, electrode should be located more efficiently, between plate and the filament. Obviously, this third electrode so located should not be a solid plate. Consequently I supplied McCandless with a small plate of platinum, perforated by a great number of small holes. This arrangement performed much better than anything preceding it, but in order to simplify and cheapen the construction I decided that the interposed third electrode would be better in the form of a grid, a simple piece of wire bent back and forth, located as close to the filament as possible.

At this time I was using a 6-volt filament energized from a dry or storage battery, which I called the A-battery; the plate battery I called the B-battery—terminology which has persisted to this day.

As the various experiments and improvements outlined took place during the period 1903 to 1906 and later, I applied for successive patents. At that time the Patent Office was not glutted as it is today, and my applications were related to an entirely new art, so that the Office issued my patents within only a few weeks or few months after filing.

Early in 1907 I conceived the idea that this remarkable wireless telegraph detector, the three-element, or grid, audion—which had already covered itself with glory in the minds of the hams and wireless telegraph operators—might also be useful as an amplifier of audio-frequency or telephonic currents. I had made some experiments in this direction, and took out a patent containing very broad claims on the device as an amplifier of currents without limitation of the frequency thereof. This patent, No. 841,387, granted January 15, 1907, has since been acclaimed as one of the most valuable patents ever issued by the United States Patent Office. The same, of course can be truthfully said about the patent on the grid electrode, No. 879,532, filed January 29, 1907.

In the summer of 1906 I presented a paper before the American Institute of Electrical Engineers describing the audion, but only as a diode *using the B-battery.* I had not then applied for a patent on the grid, or control-electrode, type, and therefore I made only veiled reference in this paper to it. The grid patent was filed on January 29, 1907.

Early Types of Audions

The first audions were of cylindrical form; later, in 1907 or 1908, McCandless suggested that it would be easier for him to construct the device in the spherical form. In the first audion the grid and plate electrodes were both brought out near the base; but in 1907 the plate and grid electrodes were brought out through the top of the tube. To distinguish readily between the two, I used a red sleeving over the lead to the plate, and a green sleeving over the grid wire—"green for grid," to be easily remembered by the operator.

In my first experiments on the audion as an amplifier for telephonic currents I added a third, or C-battery as I called it, in series with the control electrode. Although, unfortunately, I did not specify the polarity of this C-battery, the circuit diagram of the amplifier patent shows it with its *negative* terminal connected to the control electrode. This was the way I always employed it; but due to this unfortunate omission from my specification, Fritz Lowenstein was able, a few years later, to obtain a very valuable patent covering the negative bias of the grid. He was, however, by no means the first to apply this negative bias to the control electrode.

Later Audion Improvements

From 1906 to 1910 I made countless improvements or changes in the form of the audion, such as the substitution of tantalum and then tungsten for the carbon filament; the use of nickel for plate and grid instead of platinum; the double filament so arranged that if one burned out the second one could be readily connected, thus doubling the life of the detector. As early as 1907 McCandless began to pump my tubes to the same vacuum he employed in his miniature incandescent lamps. Naturally some of the tubes contained more gas than did others, and we found that a very small amount of gas made the device a more sensitive detector than those of higher vacuum. When used as a detector of wireless signals, the lack-of-linearity characteristic was of course of no importance—maximum sensitivity was what we all were after. But so long as only an "incandescent lamp vacuum" was employed, it was impossible to use more than 22 or 30 volts in the B-battery without producing the "blue arc" which at once rendered the device extremely insensitive.

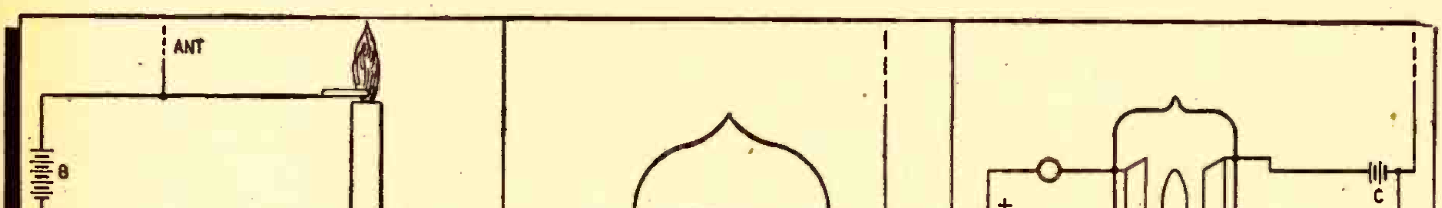
My patents show types of audions employing two, three, or more grids, as well as the "double audion" having one plate and grid on either side of the double filament. The latter arrangement developed into a beautiful oscillator, the first push-pull type in electronic history.

It was not until the summer of 1912 that I actually succeeded in developing the audion and its accompanying circuits into a genuine amplifier of telephonic currents. Seeking to make this amplifier more efficient and able to handle larger power, I besought McCandless to exhaust the tubes to the highest possible degree, to permit the use of more plate voltage. But the best that he could do still restricted this voltage to about 45. Thereupon I took some of his tubes to a manufacturer of X-ray tubes in San Francisco, who re-exhausted these to the best of his ability, using mercury vapor diffusion pumps. (McCandless had used only mechanical pumps.) With these re-exhausted tubes I was able to use as high as a 220-volt plate battery, without causing the "blue arc." Three of these high-vacuum audions connected in cascade gave amazing audio-amplifier effects, so that using as my input source a telegraphone wire on which music or speech had been recorded, and as my output device a loudspeaker of the 1912 vintage, I was able to hear the reproduction of voice and music over a distance of 100 feet or more in the open air. Thus it is evident that the approach to the radio, or amplifier, tube possessing an extremely high vacuum was merely a gradual, and perfectly obvious, result of the growing requirement for more power from the amplifier or the oscillator. More power demanded higher voltages, and it was obvious that higher voltages would necessitate higher degrees of vacuum. I never considered for a moment that there was any invention involved in the gradual evolution of the audion from a gaseous, or low-vacuum, to a high-vacuum device.

At this point in the development of the audion amplifier I was requested by my good friend John Stone to bring my demonstration apparatus from Palo Alto, California, to show to the engineers of the telephone company in the Western Electric laboratory in New York. From that point on, the further development and refinement of the audion amplifier to its present degree of ultra-perfection is well-known electronic history, and requires no résumé here.

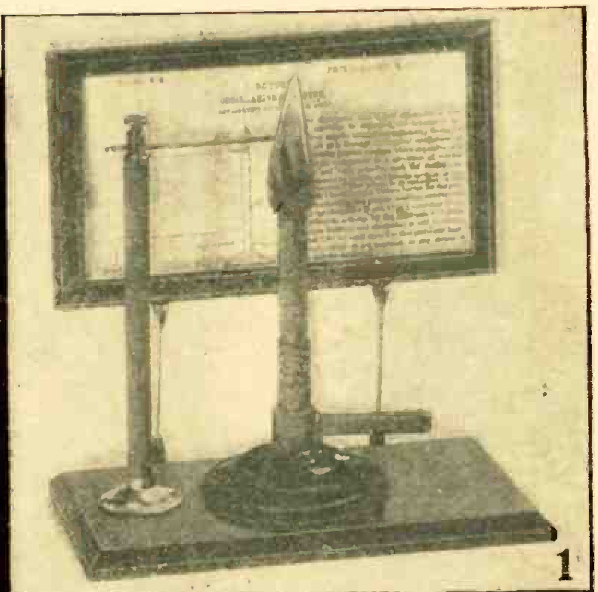
Regeneration and Oscillation

During those epoch-marking experiments in Palo Alto, in the summer of 1912, I accidentally hit upon the feed-back circuit, which made of the audion amplifier an oscillator of currents of any frequency. Thereafter began the intensive development of the "oscillion," as I then called it, in larger and larger sizes and degrees of power, until in 1915 I was employing a 25-watt power tube for broadcasting from my Highbridge, Bronx, laboratory steel tower. Simultaneously, the Western Electric engineers were developing the oscillator along very similar lines to a point where they were able, utilizing a battery of one hundred or more of these tubes, to transmit the human voice across the Atlantic without wires—a feat the prediction of which by myself, just two years previously, had been considered a ridiculous improbability, had almost resulted in my incarceration in Atlanta Penitentiary!



Evolution of the audion. Even the earliest flame detectors incorporated the B battery, as shown in the left-hand figure (Patent No. 867,878). The circuit at center (Patent No. 836,070) is essentially the same, with a heated filament in a low-vacuum tube taking the place of the Bunsen burner flame. Thus the B battery was also a feature of the earliest two-element audions. In the circuit at right (Patent No. 841,387) we see the separation of r.f. and local circuits, as well as the C battery (credit for the invention of which was lost to de Forest because polarity markings were omitted from the patent drawing). Obviously the whole series of heat detectors were thermionic relays, not simple rectifiers.

BIRTH OF THE AUDION



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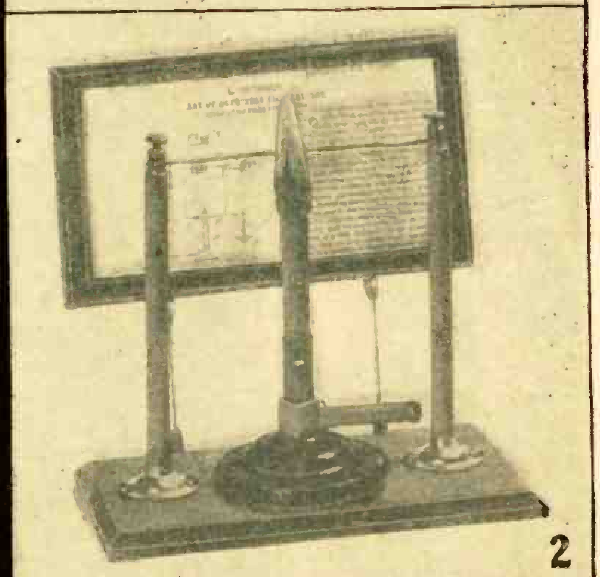

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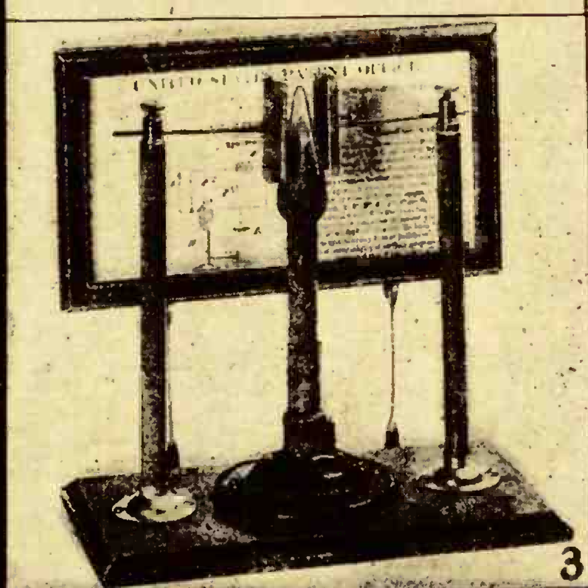
WHEN I first became associated with Dr. Lee de Forest in 1904, the dependable communication range of wireless was less than 100 miles. At that time he was driven by two ambitions—to increase the sending distance and to discover a better detector—with the greater stress on the latter. He reasoned that improved detector sensitivity would automatically increase the transmission range. None of the then current coherers, magnetic and electrolytic detectors did ever satisfy the rigid requirements and hopes of de Forest.

At this time a disaster (which upon closer analysis was not a disaster but a real blessing in disguise) occurred to de Forest. A court decision, in favor of Marconi, strictly enjoined him "to *forever* desist from the manufacture, sale or operation of *any system of wireless telegraph.*"

Penniless, but not discouraged nor beaten, he rented a small, inexpensive space in the Parker Building, then located at the corner of Fourth Avenue and 19th Street, New York City. Here he started his renewed search for a "better wireless detector." Watches, clothing, and keepsakes were pawned. His brother Charles made razor strops with a special "lick-dob" on them for sharpening the blade, which I demonstrated and sold in Hageman's drug store window across from the old Grand Central Station as new experiments began and our hopes rose.

Ultimately the audion was invented as a result of brilliant reasoning by de Forest. Up to this time all known methods of reception depended upon or were derived from the three natural elements of water, earth, and air, notably metal filings, electrolytic fluids, and iron magnets. The possibility of using fire—the fourth and only remaining natural element—was at first unnoted, but the fluttering of a Welsbach gas flame in the



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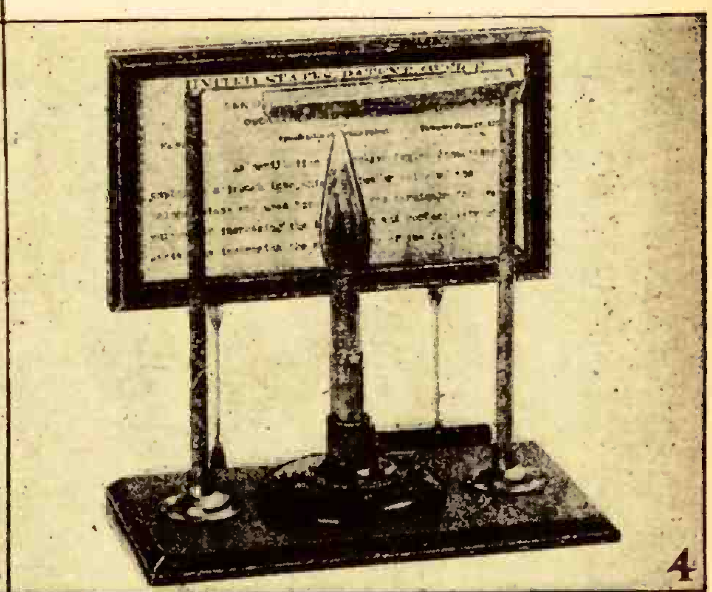

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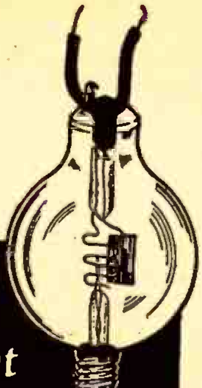
By Frank E. Butler



A first-hand account written by an assistant of de Forest throughout the hard years which immediately preceded the most revolutionary invention in all the history of radio.

presence of a spark gap was the miraculous and meager clue flashed by Fate to the keen mind which saw in it the path to his great discovery. His clue was the possibility that heated gas molecules might be sensitive to high-frequency electric waves. Such a theory was at least a *new creative thought*—not a copy or a follow-up of anyone else's idea. But, how to use it and with what? That was the real problem to solve. "Can heat hear?" was the first crude question! How was heat or gas or both to be fondled, handled, and nursed into a practical application?

As a result of de Forest's earlier preliminary tests, the fact was firmly established in his mind that the proper and only successful detector should operate upon the principle of relay action. According to this revolutionary idea some kind of automatic trigger device should control the local energy from a booster battery (from which the name "B-battery" is derived.) Activated by the incoming signals it would thus re-create the audible sound of the original transmitted signal. The plan was simple.

Assuming that a circuit were used in which the antenna impulses p a s s e d through a "gap of flame" to earth in the path of which there was inserted a telephone receiver—and provided there was even a breath of signal coming in over that route—why would it not be possible to boost or rejuvenate this feeble electrical impulse, to amplify it into audibility by the use of an electrical booster of dry cells—B-battery in embryo. With the inception of *that* idea the famous and very esential B-Battery came into being, marking the first revolutionary advance in wireless since its beginning—a step as important to radio and electronics as was Franklin's discovery of electricity during an electrical storm by means of kite and key.

Dr. de Forest believed that if two bodies adapted for use as electrodes in a wireless receiving circuit be slightly separated, the space between them could be neutralized sufficiently to enable them to act as a detector of electrical oscillations. Provided that the intervening gap be put into a condition of molecular activity by the action of heat such a condition of ionic activity would cause what otherwise would be a nonsensitive device to become sensitive to electrical wave influences. His first impression was that this could be accomplished in free air, and so it first was done. There was no intention at the start to enclose the heating medium in a container of any kind, much less the thought of a vacuum.

Imbued with this revolutionary theory of using heat it was logical for de Forest to think of an open flame that would be small, concentrated, and adjustable. He selected for his experiments an open flame as generated in the common Bunsen gas burner universally used in research work.

Several standards of various types and designs for holding or suspending the necessary electrodes were made, equipped with binding posts on top to admit the ends of the wires. They were made so as to raise or lower the height of the extended terminals which later were placed in or adjacent to the open flame. A low-power transmitter was located on the other side of the room. In this case, the distance between the sending and the receiving points was of no consequence—the ability to receive something in the nature of a signal meant everything.

De Forest's basic problem reduced to its simplest form was threefold: What kind of heat to use? What kind of electrodes to employ? By what process could neutralization of gap be best obtained? He did not

FRANK E. BUTLER was born in Monroeville, Ohio, only a few miles from the birthplace of Thomas A. Edison. Like Edison, he started his career as telegraph operator from the same location and at the same age of 15 years. On June 10th, 1904, he resigned as train dispatcher on the New York Central to become associated with Dr. Lee de Forest in the young art of wireless telegraphy, and for many years afterwards acted as his chief assistant. In 1908 he organized The American Wireless Institute, the first school in the world to teach wireless engineering. Many present-day radio executives and engineers are among his graduates, and he points out that from the ruins of this pioneer school was started, in 1911, the forerunner of the RCA Institute. Mr. Butler designed numerous early radio circuits; was sales manager of several tube companies, among them Archatron, Volutron, Arcturus and Ken-Rad. He is known among acoustical engineers as an inventor in this and the moving picture field. Is a current writer for several technical publications and the author of books dealing with the progress of wireless, radio and electronics.

realize that the answer to these three questions would spell—radio tube! His original idea of a flame augmented by the B-battery, and his ultimate development of the three-element tube with its filament, plate, and grid, are identical in theory and operation—differing only in degree—an undying tribute to the brilliant genius of Lee de Forest.

In his initial Bunsen burner tests a live flame stood between and divided two electrodes with no physical means of contact (such as a wire or other metallic medium). The heat of the gas created the "phantom medium" over which the signal might flow. De Forest chose to call this phenomenon, *ionic action,* though he might as well have called it *electronic action.*

The illustrations show explicitly and clearly the line of reasoning de Forest followed from one test to the next, even though they do not include *all* the many experiments that were tried, only to be discarded later as being impractical or not applicable. *Those shown here constitute only the major steps.* They do not represent, in the slightest, the complete research and intense analysis of de Forest as he progressed methodically and confidently with his experiments. So thorough and extensive were his tests that he applied for patents—*not one but twelve!* The first five covered his experiments with an open gas flame.

Had de Forest been interested in copying any previous experiments of others, as is so often unjustly and untruthfully claimed by those *who were not there,* he naturally would have started his research with the bulb first, but it is significant that the sequence of his patent applications shows how unerringly he pursued the path of investigating heat as the *only* avenue to lead him to his goal—a path which scientifically could not have been traveled to success in any other way. This is a highly important historical fact.

In the first experiment (Fig. 1) a common Bunsen burner was lighted and adjusted to an intense blue flame. The metal frame itself formed one of the two terminals or electrodes, thus being a part of the electrical circuit. The standard holding the second electrode was moved so that its projecting wire entered the area of the flame near the center. Obviously the electrode which was placed in the flame was of relatively higher temperature than the standard itself which formed the other electrode. Thus was formed a local receiving circuit possessing a certain asymmetric electrical conductivity which permitted the current from a few No. 6 dry cells to pass from the relatively cool burner stand to the more highly heated one. (Current in 1906 *always* traveled from positive to negative.) Fortunately the adjustment of the terminal wire in the flame during the first trial was *perfect*—quite by accident—otherwise no signal could have been heard. But there was no mistake about this! The signals were very weak, yes—but nevertheless they were *real* reproduced signals sent across the room.

This initial test brought out two important results: First it proved that heat was effective in detecting wireless waves. Second it witnessed the birth of the B-battery—the importance of which cannot be emphasized too much, because without this simple adjunct our present-day radio and electronics would not be possible.

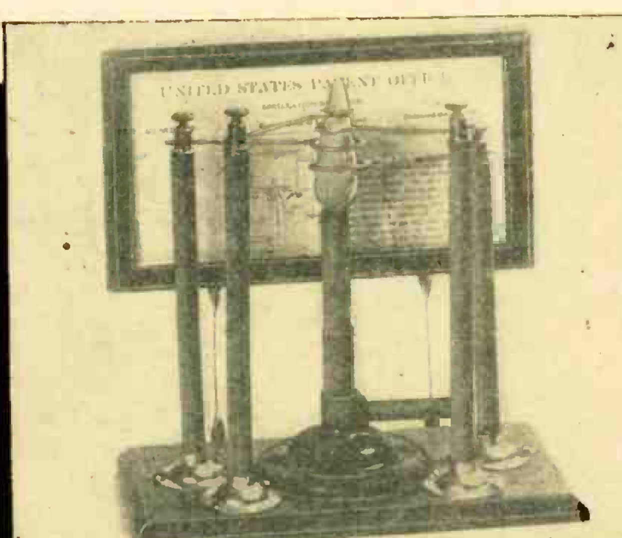
The second test (Fig. 2) was prompted by a query which in itself seemed trivial, yet it was fraught with great possibilities, as later test proved.

"If one electrode in a flame produced such promising results—what will happen if two terminals be immersed in the flame, and are different spots in the flame more sensitive than others?"

Then another test (Fig. 3) suggested itself. Instead of using two plain points of wires as terminals, why not employ "blinkers" or reflectors at the end of terminals, and deflect or concentrate the "ions" across the flame. Another test consisted of two wings—first plain flat pieces of metal, then perforated ones.

It was observed that the extreme outer edge or envelope of a flame appeared to be the most sensitive spot and there was a difference in signal strength between a cool wire just approaching or touching the flame and when, a moment later, that terminal tip became red hot. It was also noted that varying the voltage of the B-battery produced a marked difference in results. Every disclosure was startling in effect and heightened the curiosity and anxiety of de Forest to probe even deeper into this fascinating research.

The next test (Fig. 4) was a radical departure from the previous ones and illustrates the wide range of the inventor's imagination. This consisted of a trough-like electrode suspended horizontally above the flame. Various crystals of potassium, halogen sodium salts, etc., were placed in the trough, and when heated would emit different gasses or rarefied heated air. Parallel to this



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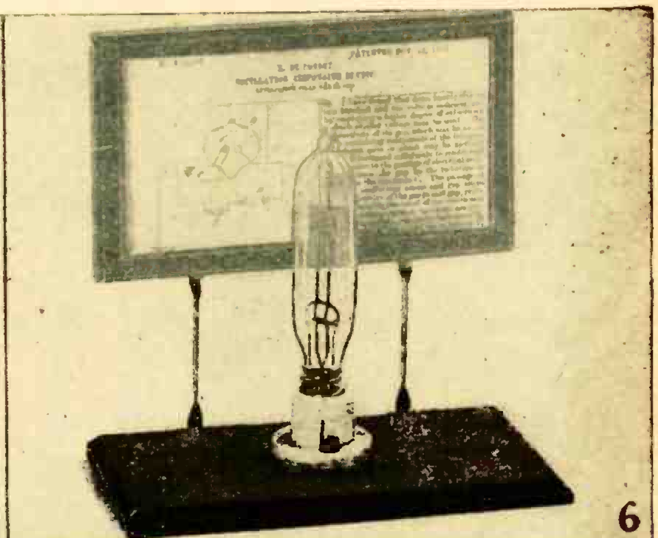

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trough and above it was suspended a straight wire of the same length, this being the second electrode. The idea of using salts was to improve the sensitivity of the gap by further increasing its molecular activity. This was perhaps de Forest's inception of a "rarefied area" such as only an evacuated medium could produce—a radio tube in embryo.

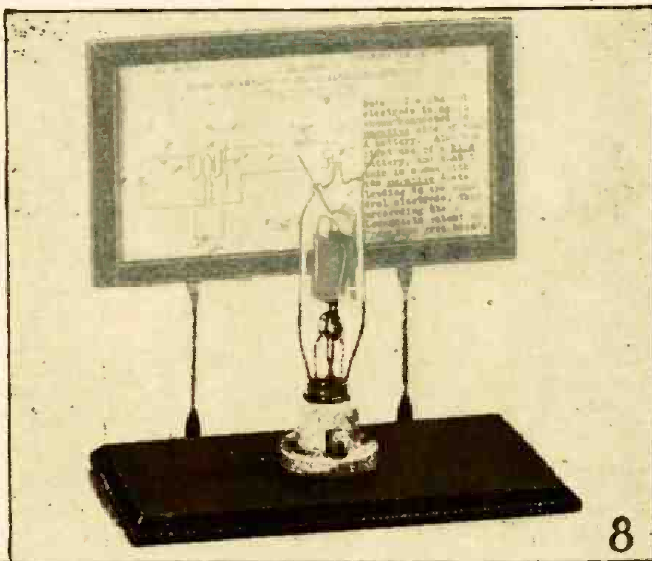
Then followed the introduction (Fig. 5) of four terminals in flame arrangements. This time the ends of the electrodes were made with *rings* of slightly different circumference so that each terminal could snugly encircle the flame, one ring on top of the other and each leading to a different part of the circuit. This test again shows de Forest's original idea of keeping the high-frequency current path distinct and free from that of the local telephone current—the idea of separating the high-frequency from the audio circuits. It was in this experiment that de Forest obtained his first vague idea that the influence of high-frequency impulses could be impressed to better advantage on the conducting medium by means of a *third electrode* (the "grid").

It now seemed that de Forest was running into a log-jam among so many results—each of which presented its own set of baffling problems. The situation was bewildering—the search too intense. Anything might or could happen to precipitate a crack-up. It was this latter specter that haunted de Forest, for although he had learned a great deal about the action of heat and its relative importance to wireless detection, yet once again it was a whiff of air that turned the tide against him just as it was a whiff of air that feebly fluttered the Welsbach burner that originally inspired him. He had observed that the slightest draft of air could blow the flame out of its delicate adjustment—thereby altering the action and rendering the reception unstable. This observation sent de Forest into despondency as it convinced him that no matter how successful his flame tests might be—or whatever type electrodes he might use—its practical use, as for instance on shipboard, was impossible. At last—the realization that the dead end of a street had been reached.

The instability of an open flame and its susceptibility to drafts then caused him to shift to *another type* of heat-producing medium in an attempt to find the necessary steadiness. There seemed nothing quite so handy, practical or promising as a lighted incandescent electric lamp.

The first thing to be decided was the voltage and the number and kinds of electrodes to use. It was de Forest's intention to follow the series of bulb tests along the same sequence as was done with the flame. It would take longer, but at least give the benefit of comparisons. A Christmas tree lamp with its small candelabra base and low voltage was considered the most advantageous type. This style of lamp was obtainable locally from a manufacturer named McCandless Incandescent Lamp Co. However, making up only two or three samples of electric lamps which possibly would burn out after only a few moments' trial presented a real financial problem. It required unusual skill on the part of McCandless to construct the various electrodes and then to evacuate the tube with a hand pump before sealing. Sample after sample was discarded and yards of glass tubing sacrificed before the first crude specimen (Fig. 6) was produced. Then followed bulb after bulb, made along the same lines as the previous flame-tests. Each produced varying degrees of good or bad results—representing a maze of baffling problems. Then followed a test with a tube in a horizontal position (Fig. 7) designed with a small cup on the bottom which held a portion of mercury.

The next test, using two wings (Fig. 8) is especially significant. It is not only the original amplifier, but it also introduced for the first time the use of a "bias C-battery" clearly shown in the patent drawing with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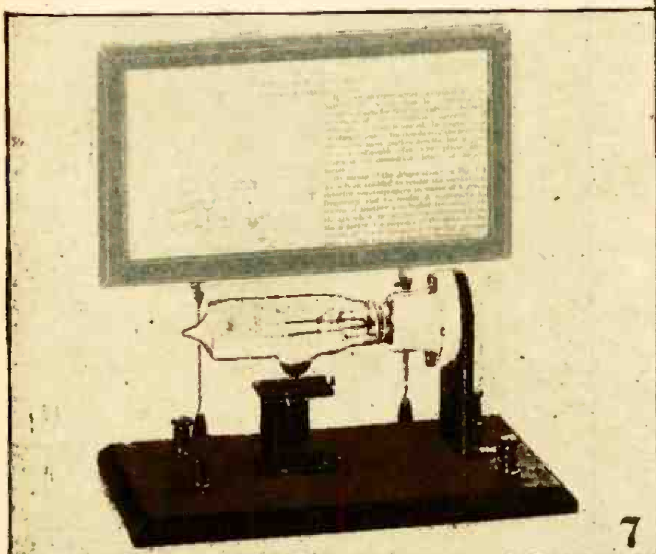
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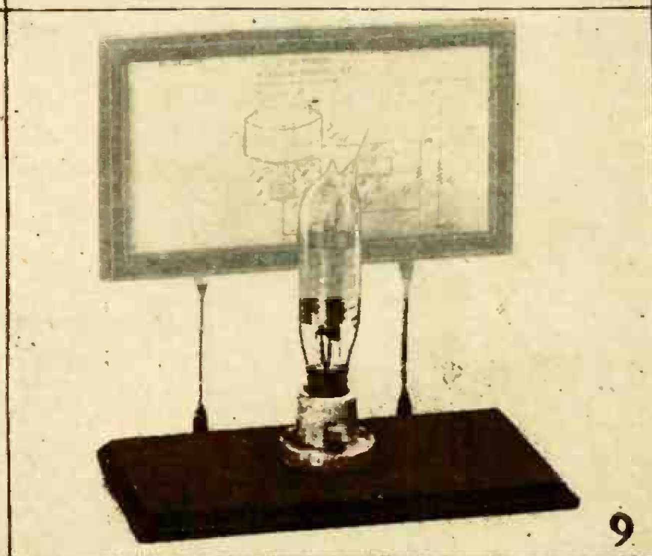
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its negative plate leading to the control electrode—unassailable direct evidence that the idea of "negative grid bias" positively was originated by de Forest (though it later meant a fortune to those concerns controlling the Lowenstein patents).

With this idea fresh in mind de Forest next tried a tube having only one wing and filament. He pasted a strip of tin foil on the outside of the tube (Fig. 9) which he used as one electrode—but this produced no favorable result. A safety razor blade was lying within reach. Preoccupied with many thoughts de Forest carefully cut the tinfoil—round and round—into a long spiral piece like a spring, without changing its location where it was pasted. This simple act had the effect of making a *coil of flat metal* instead of a flat plate—two quite different and distinct things electrically. This was hooked up and tried. The result was startling. Hopes rose. This also was the time a 6-volt storage battery with adjustable resistance was used for filament supply. Likewise the amount of B-voltage was set at 22½ volts with a potentiometer for varying its potential—two items that remained standard in future radio circuits for many years afterward.

Experiments were continued with a wire instead of a tin-foil spiral. De Forest figured he had too much wire wound around the tube, which luckily was a sturdy one, able to withstand the series of additional tests. Signal strength continued to increase as he kept constantly snipping small pieces of the coil to reduce its length.

Finally when only about 1¼ inch remained of the original coil—not even enough to completely encircle the glass—he obtained his greatest results, and he stopped there. Feverishly he took this small length of wire and with a pair of long-nosed pliers bent it into a flat zig-zag shape having the over-all dimensions of the flat ⅝-inch wing. This was taken over to McCandless. Dramatic and intense moments followed.

"It is my impression," said de Forest, "that if we take this zig-zag wire and place it *on the inside* where it will be closer to the hot filament and the cold wing we'll notice a decided improvement. *In fact I believe the closer we group the three elements the more effectively they will operate.*"

At this point de Forest sketched the idea he had in mind. Here again was shown the *third* or C-battery in the input circuit. This indispensable C-battery, like its big brother B-battery were both discovered and used before their famous sister the *grid* came into existence!

Several sets of tubes were made with the elements in different locations. Each was carefully tried. One of these was made with the zig-zag wire interposed between the filament and the wing. By a streak of fortune this was the last one to be tested.

Disconnecting the previous tube, de Forest reached for the remaining specimen that was still resting in the old shoe box filled with cotton batting in which it was brought from the McCandless shop.

In that unforgettable moment, de Forest gently held this remaining tube in his hand as if he had a premonition of what promise it had in store for him—and mankind. When all was in readiness again, he called across the room saying:

"O.K., Frank! Let's have some signals!"

Immediately I started sending the familiar "Dash-dot-dot"—of the letter D with the same monotonous action I had been accustomed to for years, with no special thought that this was an exceptional occasion. Two or three D's had been made when my senses were jarred by the wild, almost frantic yell from de Forest saying:

"That's it, Frank! My God, you ought to hear those signals! I never heard such perfect D's before—Here take these phones quick and let me send it to you."

He dashed toward the transmitter—passing me as I rushed for his headphones where I too listened in amazement at the quality and strength of signals.

At last de Forest's dream had come true. That moment saw the birth of the "three-element vacuum tube" (Fig. 10). Our "better detector" had become a reality.

The life of that pioneer tube was scarcely *three minutes* before it burned out. In that short and glorious life-span it had accomplished what none of the human race had ever seen or heard since creation. It was the first messenger from Cosmos chronicling the harnessing of the electron. Its sound, though weak, was strong enough in its message to echo throughout all future ages. Its infant range was merely the length of a dingy room—a far cry from that of its offspring today which girdles the earth and reaches into the infinite space of the planets.

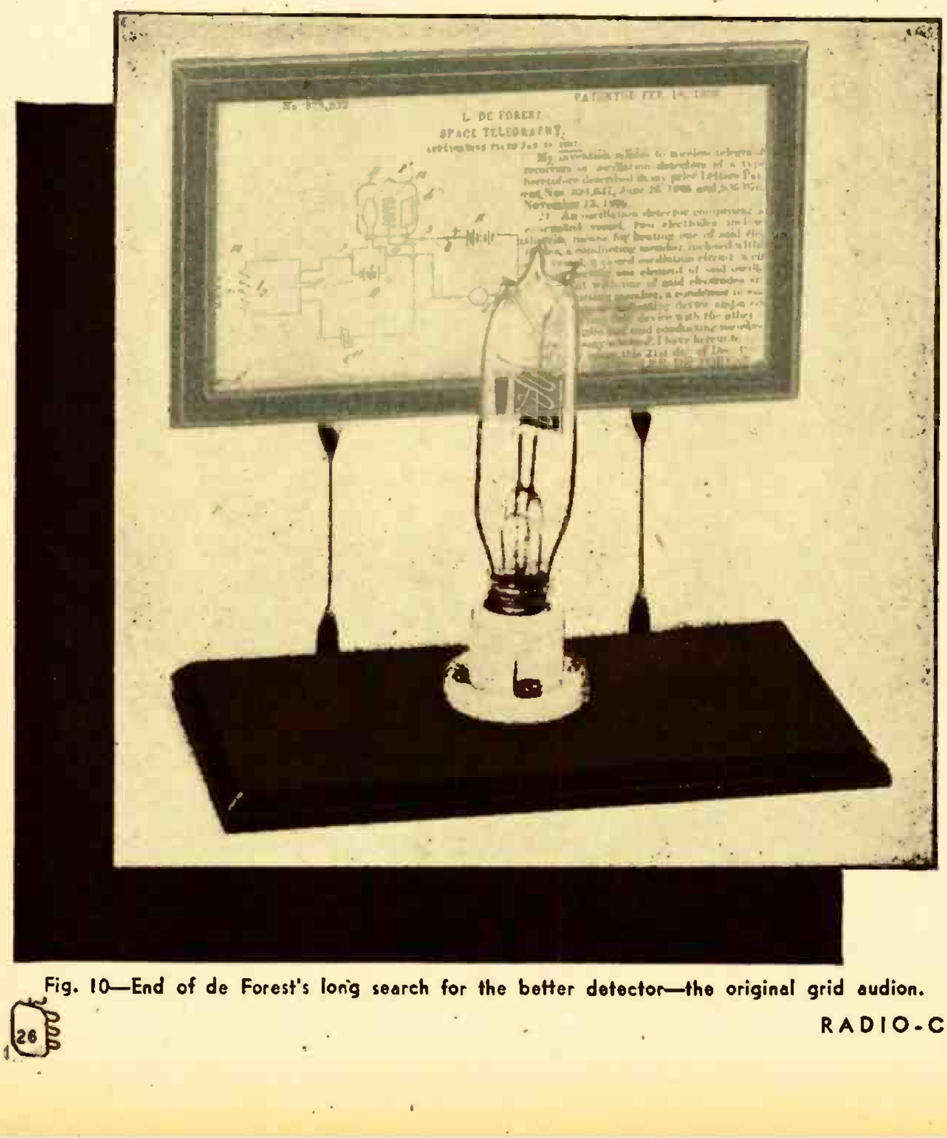
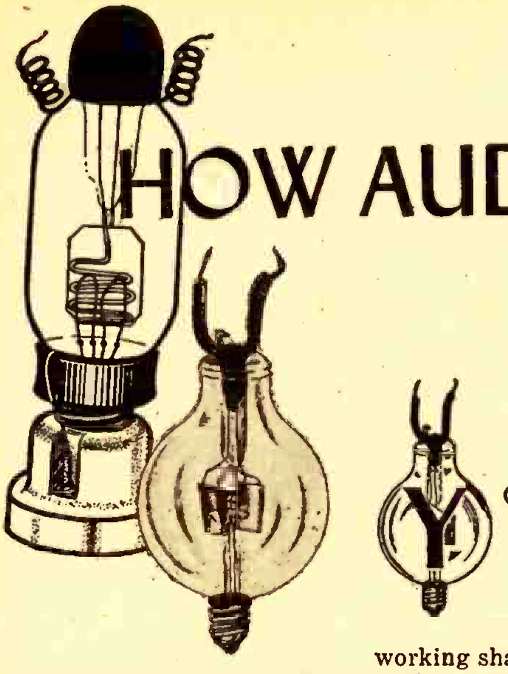


Fig. 10—End of de Forest's long search for the better detector—the original grid audion.



HOW AUDIONS WERE BUILT

By Gerald F. J. Tyne

"YOU AND your factory foreman . . . put the invention in practical working shape and handed to the world a useful device . . . a more meritorious act than the simple dreaming that it could be done." So wrote Lee de Forest's assistant, C. D. Babcock, to H. W. McCandless on December 9, 1913. Behind this letter lies one of the greatest success stories of the early days of radio, a story unfortunately not too well known.

Henry Wallace McCandless, guiding genius of the firm of H. W. McCandless & Company, Inc., was graduated in mechanical engineering from the University of Illinois in 1890. In 1895 he founded his company and engaged in the manufacturing of miniature incandescent lamps at 67-69 Park Place, New York City. In the ensuing years he built up a reputation for being able to make special lamps of all types. His work and reputation were such that large lamp manufacturers referred their orders for special lamps of unusual design or characteristics to him. Because of his knowledge of materials and the techniques of handling them, he was able to fulfill the most bizarre requests. As he developed new techniques for handling glass and metals, he also made lamps of his own design for special applications. Few realize that even in the field of surgery part of the progress made in those days may be attributed directly to the lighting developed by McCandless.

Experimental Pre-Audion Tubes

When Dr. de Forest and his assistants were struggling with the idea of the audion, it was but natural that they should turn to the foremost lamp-maker of the day to have their models made. Toward the latter part of 1905, C. D. Babcock, one of de Forest's assistants, came to McCandless with a crude lamp and asked if he could duplicate it. The sample had a flat anode and was unbased. Babcock said that de Forest was working on a wireless telegraph detector, that he had tried an experimental form using a gas flame, and was now desirous of replacing the gas flame by an incandescent filament.

Accepting Babcock's order, McCandless cut the sample apart and made six copies of the model. These bulbs had a carbon filament and a nickel anode. Two days later Babcock came back and brought de Forest with him to discuss the bulbs.

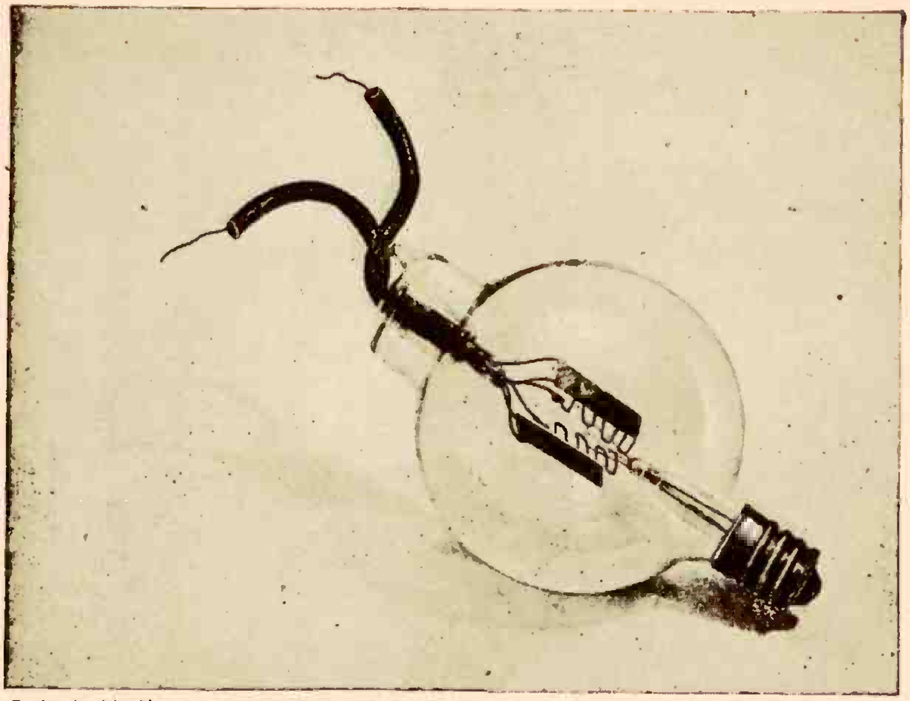
While the first order was a duplication job, subsequent orders were for bulbs made up in accordance with sketches, usually extremely rough ones, provided by Babcock or de Forest, who called these devices "audions." These were all essentially two-electrode devices (filament and anode) and the lead to the anode was brought out through the wall of the glass bulb, sometimes at the top, sometimes at the side.

The First Order for Audions

In the fall of 1906, de Forest and Babcock ordered a large quantity of tubes, all alike. When McCandless received the large order, he assumed that these men had at last found exactly what they wanted. However, they returned in December of that same year and asked him to make up more models, this time with a zigzag wire grid between the filament and the plate, or "wing" as it was called at that time.

The earliest of these "grid-type" audions had carbon filaments of the treated type, the grids and wings were of nickel, and the bulbs were cylindrical. They had single filaments, but double filaments were soon introduced, and the records of the McCandless Company show that the first double-filament types were made in 1906.

Henry Wallace McCandless, who built the first audions.



Early double-filament, double-grid and double-plate audion, now owned by Louis G. Pacent.

The first double-element type (plate and grid on each side of the filament) was made in April 1909, but the single-element type continued to be made for some years thereafter. These double-element tubes were known as "double audions," and were sold by de Forest at a higher price than the single-element type. A number of these double audions are shown in the attached photographs.

Contributions by McCandless

It was evident to McCandless that these men were experimenting and as usual he drew on his wealth of knowledge to make suggestions as to how the tubes might better be made. The earliest tubes had all the elements mounted on a single stem, although the leads for the grid or wing, and sometimes for both, came through the side of the bulb instead of through the "press."

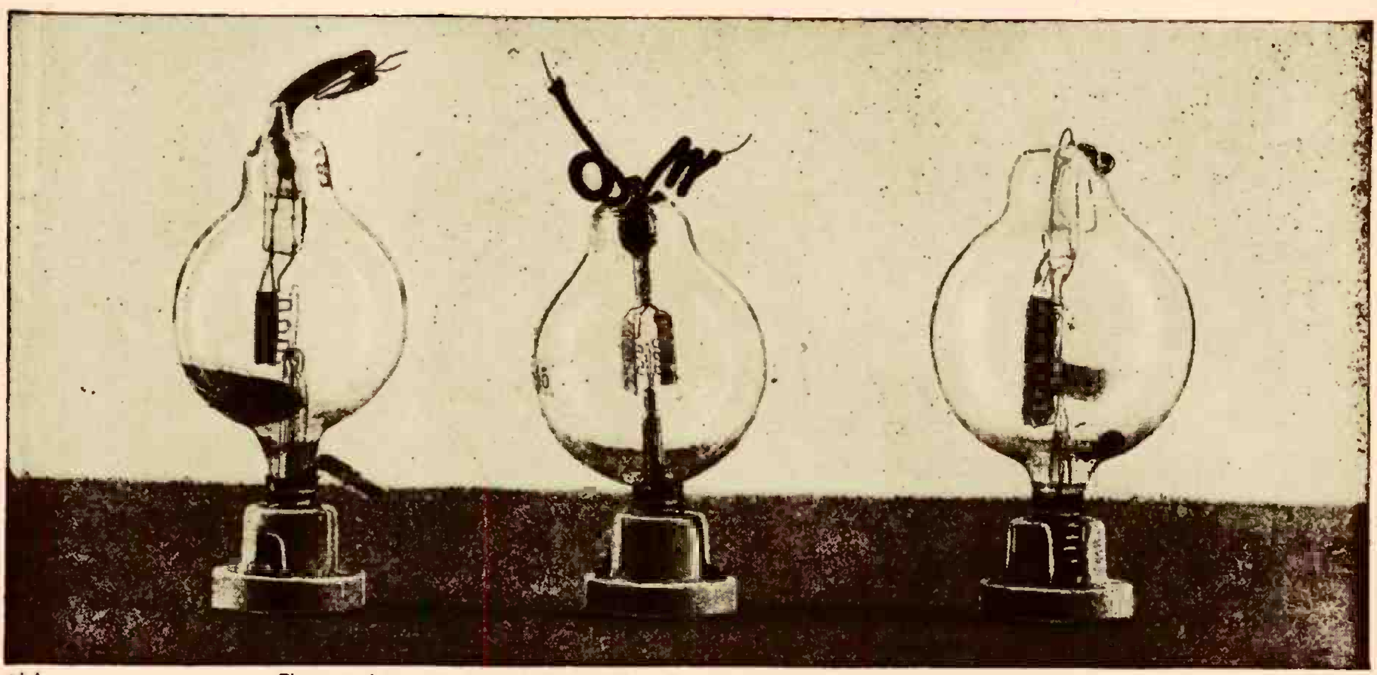
McCandless and his shop superintendent, Jacob C. Grogan, felt that the audion would not become a commercial product until the tubes were designed with the grid and wing on one stem, and the filament on another. The purpose of this was, first, to keep the leads separate and, second, to save the loss of audions due to burning out of wire filaments during exhaust. With the double-ended assembly it was easy to cut off the stem of the bulb, splice on a new neck and seal in a new filament and stem, thus saving the bulb.

While this development work was going on, McCandless was working on another project. For a long time he had wanted to make a satisfactory incandescent lamp to operate at two volts, so that it could be used on a single storage cell. The characteristics of the available carbon filaments would not permit this, with the filament diameters available. The filament had to be so short that only the center part glowed, the temperature of the end portions being reduced by conduction of heat through the supports.

Improvements in Filaments

In 1906 a friend brought from Germany one of the newly-developed *tantalum* - filament, 110-volt incandescent lamps, which were then little known in the United States. McCandless broke open this lamp, and using approximately 1/55 of the length of the 110-volt filament, made up a two-volt lamp which was successful. He then tried to obtain additional tantalum wire from Siemens & Halske, with the understanding that it was for use in lamps operating at less than ten volts filament. Although he made some progress in the early stages, negotiation was never successful because of patent difficulties. He did manage, by working through the Association of Lamp Manufacturers, to get limited amounts of this wire from the General Electric Company.

McCandless decided to try tantalum-filaments in the audion. It was a



Three evolutionary steps. Left is 1908 audion, center a 1910, and right a 1912 type. *Courtesy G. F. J. Tync* good inspiration, since it improved the electrical characteristics considerably, but it had its disadvantages. It was not stable in position. When heated it would not remain in a plane, but would twist around to such an extent sometimes as to touch the other elements. The important thing was that it could be made to operate at four volts. Carbon filaments required at least six volts for satisfactory operation.

About this time tungsten filaments came into the picture, and McCandless, ever on the lookout for methods of improving the quality of the audions he made, tried them. The tungsten filament of that day proved to be little better than carbon and far inferior to tantalum.

The suggestion was made—by whom McCandless does not remember—that a tungsten filament be used because of its rigidity, but that it be wrapped with tantalum to get good emission. Always open to suggestions, McCandless tried this expedient. It was successful. The combination was as good electrically as pure tantalum and as good mechanically as the carbon filament.

Soon after the first tubes were made for de Forest, in 1905-1906, a young man came to McCandless and wanted to buy some audions. McCandless consulted de Forest who told him: "Sure. Sell them to him." This McCandless did, and the word spread, so that more and more tubes were sold on an over-the-counter basis.

One of these customers, who first came to buy shortly after McCandless had introduced the tantalum-wrapped tungsten filament, was Dr. Walter G. Hudson, an enthusiastic amateur, then chief chemist for du Pont. McCandless showed him the audions with the tantalum-wrapped filament and told him that the wrapping was an extremely tedious and time-consuming operation. Hudson bought some of the tubes, and after he had used them came back to McCandless and said:

"I have an idea. Let me try it, and if it works I'll patent it and go fifty-fifty with you if it proves saleable."

Hudson's plan was to grind the tantalum to powder, make a paste of the powder by adding a binder, and applying the paste to the loop of the tungsten filament. Hudson provided the paste and the audions made in this manner were very satisfactory. In fact the "Hudson filament" type soon became the "standard" audion.

During these years of development work on the audion, McCandless was not focusing his attention on materials alone. He was also experimenting with the shape of the tube and the positioning of the elements therein.

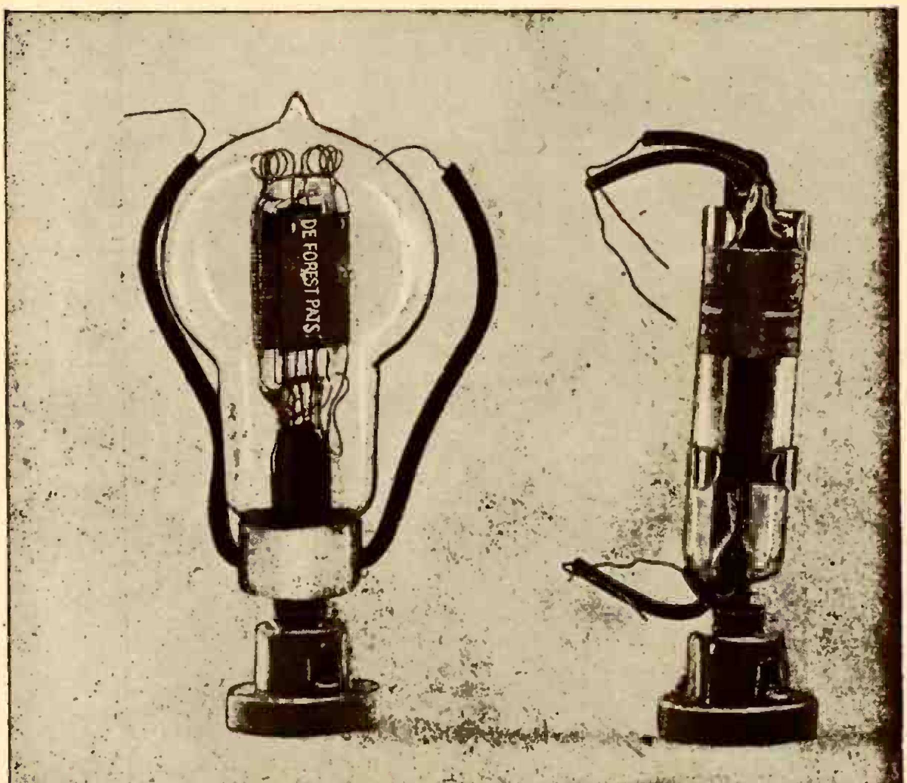
Better Pumping Equipment

The early audions were made with the vacuum ordinarily obtained in the incandescent lamp of that day. When McCandless began to manufacture miniature lamps, he used an exhaust pump of the "Packard" type. Later he added so many improvements to this that it became known as the "McCandless pump." At that time no pressure gauge was used on the pumping equipment. To determine when the proper vacuum was attained the mercury valve which checked the back-rush of air into the pump was watched. The tubes were pumped until practically no bubbles appeared at that point. The bulbs were checked for leaks with a high-tension spark-coil device, commonly used by incandescent lamp manufacturers for that purpose.

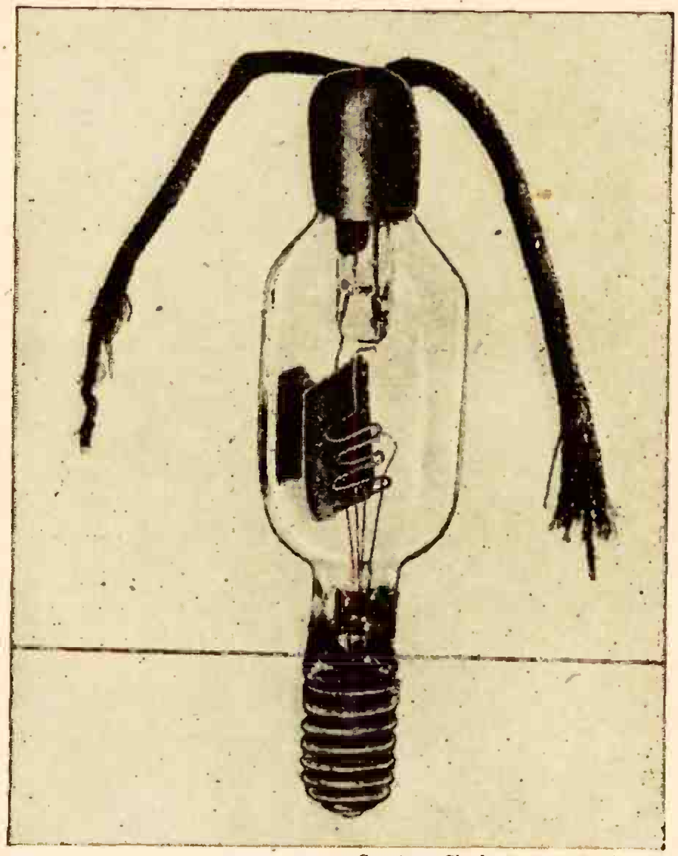
De Forest kept demanding higher and higher vacua in the audion. Later, for higher vacua, the tubes were baked in an oven to a very high temperature while still on the pump. In some cases the bulbs were heated, by the direct application of a Bunsen flame, almost to the collapsing point. This was done to expel all the gas occluded in the glass bulb.

A few years later, in August 1910, McCandless replaced his pumping equipment with two rotary pumps of the Gaede type (not the Gaede molec-

Courtesy R. McV. Weston, F.R.P.S.
A 1907 audion, once owned by J. A. Fleming.



Courtesy G. F. J. Tyne
Left—An early de Forest "Singer Type" audion. Note the metal base. Right—An Ultraudion with Hudson filament mounted in an adapter to permit operation in candelabra socket.



Courtesy Clark Historical Library
Very early type of three-electrode audion, made in 1907 and 1908.

Reconstruction of the 1907 appearance of the building at 67-69 Park Place, New York City, where the first Audion was made by McCandless.

ular pump). A third such pump was added in February 1911. De Forest continued to demand higher vacua in the audion and sometimes returned the bulbs for re-evacuation, complaining of a lack of "sensitiveness." Grogan insisted that the lack of sensitiveness was caused by pumping the tube to too high a vacuum. This was particularly the case while de Forest was on the West Coast with the Federal Telegraph Company, where he was trying, in 1912, to make the audion function as an amplifier.

Detector vs. Amplifier

Here is a confusion of the terms "sensitivity" and "output." In the case in question de Forest, on the West Coast, was trying to get high output by operating at high anode voltage. The tubes would not give output, hence he said they were not "sensitive." What he meant was that he could not get the desired amplification at high power levels because of ionization of the residual gas. The gaseous tubes advocated by Grogan and operated at low anode voltage would *detect* lower voltages but would not give high power output.

McCandless made a number of audions for the Federal Telegraph Company while de Forest was with them.

In the fall of 1912 de Forest came east with a view to interesting the telephone company in the amplifying properties of the audion, for its use as a telephone repeater. After he had demonstrated the device, de Forest left the apparatus with the engineers of the Western Electric Company, and gave them permission to purchase additional bulbs from McCandless for their experiments. McCandless made for them two types of bulbs. The first was a tantalum-filament double audion, and the second a single audion, but having larger elements and a larger bulb, with a longer, higher-voltage filament of tantalum. These tubes are shown in the photographs. The larger elements were used at the suggestion of Grogan.

Some time prior to 1912 the Marconi Company took official cognizance of McCandless' work on the audion. Mr. R. W. Sammis, then chief engineer of the Marconi Company, in a preliminary telephone conversation offered to give McCandless the job of making Fleming valves for his company, provided he would stop making audions for de Forest. Sammis later wrote McCandless a letter transmitting to him a copy of the Fleming patent and stating that it covered the audion and in fact any type of rectifying vacuum detector. McCandless consulted an attorney, Charles McCandless (not a relative, however), and they studied the Fleming valve patent. Meantime, after the telephone conversation, but before the letter from Sammis, McCandless became very much concerned over the situation and wrote de Forest about it. De Forest replied, on March 2, 1912, giving a list of the patents covering the various embodiments of the audion, and assuring McCandless that he was fully protected. McCandless obtained copies of all the patents, and after due consideration decided to continue the manufacture of audions.

Sales to the general public were negligible after 1913. De Forest started to make tubes himself at his High Bridge plant and "bootleg" manufacturers started up. McCandless never advertised or solicited trade in audions. He continued to make special bulbs for de Forest or any other customer who came to him with a problem which was a challenge to his genius. He sold his business to the Westinghouse Company in 1914 and entered their employ as manager of the Westinghouse Special Lamps Division.

Courtesy G. F. J. Tyne

A 1916 tube, last of the screw-based audions. It was made at de Forest's Highbridge plant.

To this day the concluding paragraphs of Babcock's letter written about that time must bring back a stirring flood of memories to McCandless:

The Tribute from Babcock

"The mechanical and electrical development of the device from those crude designs of mine to the perfect instrument of the present day should and does stand as a monument to the skill, patience and technical knowledge of your Mr. Grogan. Particularly valuable was his disclosure to de Forest that the audion should not be exhausted to a vacuum known as 'hard,' but rather should be 'soft,' that single fact took the device from the ranks of failures and put it in the category of successes.

"Facts are stubborn things, and the above are some of the stubbornest in the history of this instrument. The great pity is that the thing never became more generally used so that you could reap the reward due you for the part you and your staff played in its development."

DE FOREST AUDION 1907—1947

Three Anecdotes of the Audion's Early Days

How the Grid was Named

During the early experiments with the first crude handmade radio tubes it was the custom of Dr. de Forest to give directions to his assistants somewhat in the following manner:

"Here . . . hook this to that—and that to this. Bring this wire over to that post and move this over there."

In the rapidly shifting tests it was at times, difficult to differentiate between what was "this, that or the other thing," so one day, in a state of exasperation, an assistant impulsively asked:

"Doc, why don't you name some of these parts so we'll know what you're talking about and what we are doing?"

"All right," snapped de Forest in reply. "You know what the filament is and which is the 'wing' (now known as 'plate') so we'll call this other jigger—the GRID,—because that's what it looks like—a roaster grid." Then, quickly adding, as if it were equally important:

". . . and remember this . . . in fact make a sign and paste it on the wall: REMEMBER, GREEN TO GRID and Red to Wing."

To this day that order has never been countermanded and we find that in every country in the world where electronic circuits are planned or used the "lead to grid" is always specified in the color code as—GREEN!

De Forest's Nickel

One day as Frank Butler was entering the open door of Dr. de Forest's laboratory in the Parker Building he hesitated at the entrance and saw no one inside. Just as he was about to step forward across the threshold a slight sound came from behind the door and he heard the voice of de Forest unconsciously muttering to himself these words:

"Humph! I don't know whether to get a sandwich with this nickel or to buy a pad of writing paper. . . ."

In an instant the two were facing each other and the sudden, unexpected meeting took de Forest so by surprise that he dropped the precious coin so it rolled underneath the nearby empty shipping boxes which constituted the workbench. This placed the inventor in the predicament of not knowing which to do first—retrieve the coin or greet Butler who was then returning from an out-of-town visit.

This is but a sidelight upon the impoverished conditions under which Dr. de Forest was often compelled to exist in those early days.

Navy and the Audion

A short time after the first few audions were made, Dr. de Forest took his original mahogany receiver cabinet with the "peep window" in front, together with a seven-plate Witherbee storage battery to the Navy Department in Washington hoping to interest them in his new discovery. The story of how "they entirely missed the boat" is a classic example of many similar incidents ascribed to dumb officialdom.

The several officers rendered an unfavorable decision based upon six counts:

1. The device can in no way be of service to the department either on land or sea.

2. The device is found impractical.

3. It is undesirable on shipboard because the motion of the ship at sea would permit the battery fluid to escape from the vent holes of the battery, splashing the acid on and ruining the deck of the wireless room.

4. The price of $30.00 is excessively high in comparison with a good crystal detector.

5. The device is short lived and bulbs would have to be replenished too often.

6. It is regarded as unreliable and unwanted because it is too new. It is untried. *It is not Standard Equipment.*

DE FOREST AND THE NAVY

By George H. Clark

DR. LEE DE FOREST and the wireless companies bearing his name have been associated with the United States Navy's wireless communication system since its early days, and in the opinion of the writer have had more direct and indirect influence on the development of the Navy's wireless than has any other person or company up to the beginning of the recent war.

One honor is not his, however—that of first introducing the U. S. Navy to wireless communication. That is reserved for Guglielmo Marconi, who came to the United States in the fall of 1899 to report the International Yacht Races by wireless. The Navy Department appointed several officers to observe and report on this work, and the first wireless message in the Navy's history was sent by Lieutenant Blish, U.S.N., on September 30, 1899, from the Marconi-equipped observation vessel, the S.S. *Ponce*, via the Lighthouse Service Station at the Highlands of Navesink, N. J., first U.S. shore station.

Four years later, however, de Forest came into the picture, submitting to the Navy one of his sets for competitive test against those of Slaby-Arco, Braun, Rochefort, and Ducretet. The Slaby-Arco set worked 70 miles from shore to ship, de Forest's only 42; the others made no record worth mentioning. On the basis of distance attained, the contract went to the German concern.

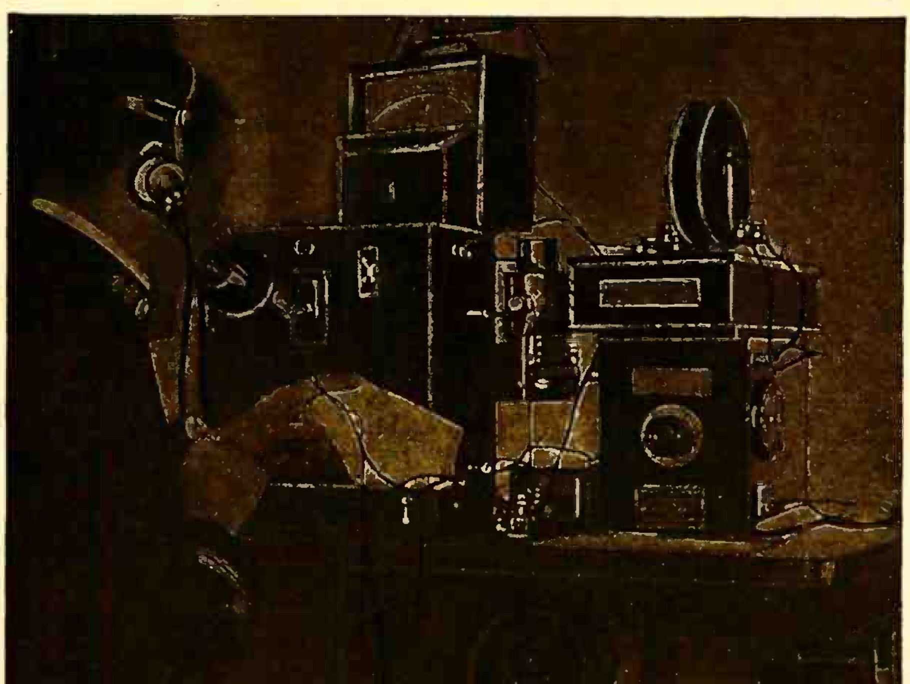
De Forest Equipment Better

As a matter of fact, de Forest's set was in some ways far superior to that of the Germans, although this was not recognized by the Navy authorities at the time. Two of the features which he submitted were later adopted as standard: (1) *the use of alternating current* as a power source instead of the interrupted direct current used by Slaby; and (2) *the use of a self-restoring detector with telephonic indicator*, as opposed to the Slaby coherer. The Navy considered the use of the coherer, with its tape register, essential for the relatively untrained Naval operators of that time. The message could be read off slowly from the tape at any time after its receipt if the operator were not sufficiently trained to copy it directly from the buzzing sound of the decoherer. Also—an important factor in those days when operators were few—a bell could be switched into the circuit instead of the recorder, to call the operator if he were away from the set or if messages came in during his sleeping hours.

The advantages of the alternator which became painfully obvious after Navy men had spent weary hours cleaning the mercury-turbine interrupter of the Slaby system, were not appreciated (or rather foreseen) in the early experiments.

One of the early tests of de Forest sets was held between the Naval Academy at Annapolis and the Washington Navy Yard, and during the work the Secretary of the Navy visited the former site on an official inspection. The Secretary suffered a slight accident at the time — some sources say he tripped over a wire, another that the horses drawing his carriage ran away; but at any rate the de Forest operator, Harry Mac Horton, sent a little story on the event to de Forest in Washington. The latter, even then publicity-conscious, rushed up the narrow street to the Navy Yard gate, and telephoned the news to the Navy Department, whence it was sent to the local newspapers. Thus the "first press story" by wireless was in the Navy's realm, using de Forest apparatus. Nor was it the last!

The Slaby system soon became antiquated, and in time American manufacturers were given orders for sets. Thus such well-known inventors as Fessenden, John Stone Stone, and (by no means least) de Forest began equipping Navy ships and stations. As early as 1906, there were 12 de Forest spark sets in use by the Navy.



Courtesy Gerald F. J. Tyne

Lt. Weaver using the de Forest radio telephone aboard the U. S. flagship *Connecticut*.

GEORGE H. CLARK is one of the earliest of radio pioneers. He was the first radioman to be graduated from the Massachusetts Institute of Technology (In 1903). Joining the Stone Telegraph and Telephone Co., he remained till 1908, when he became the Navy's "Sub-inspector of Wireless Telegraph Stations." He remained with the Navy till after World War I, when he joined the Marconi Wireless Telegraph Co., remaining with it and its successor, RCA, till his retirement from active work in 1946.

From the time he started with the Navy, Clark's work led him to value the importance of the written record. First setting up specifications for apparatus, then installing a system of type numbers for equipment, he was drawn more and more toward "a bookish career" till he became the official historian of RCA and the semi-official historian of radio in the United States. His collection of records amounted to more than one hundred volumes when he left the Navy, and has been supplemented since then by purchase and gift. Therefore his article is based on something considerably more solid than recollection, and as such, has more than usual authority.

Three of these, the 25-kw shore stations installed in the Caribbean and at Puerto Rico, made spectacular records, the last-named being able to communicate directly with the de Forest commercial station at Manhattan Beach, N. Y., a distance of 1,600 miles. This was of course (as we used to say in those days) "at night, in the winter time," but it was a record nevertheless. The U.S.S. *West Virginia*, equipped with a de Forest set, while en route to the Canal Zone with President Theodore Roosevelt on board carried on wireless communication with ships off Key West, about 1,050 miles away. These were remarkable feats for the time and the apparatus. Nor were these isolated cases; they were repeated many times.

Much of the success of the de Forest spark transmitters was due to three things: his appreciation of good grounding (at Key West his ground plate was deeply laid, in water, but the water happened to be a man-made lake, with coral between it and the ocean; not until a hole was broken through to the latter did the station begin its record-breaking work); his use of a very large primary condenser and a short spark, thus lessening the resistance of the latter and making for more sustained oscillations; the fairly loose coupling obtained, due to the large primary condenser, between primary and secondary circuits, even with a direct-coupled set. In addition, the large condenser gave him multiple discharges and hence a spark note more easily readable over static and over the lower tones of sets such as those of Slaby.

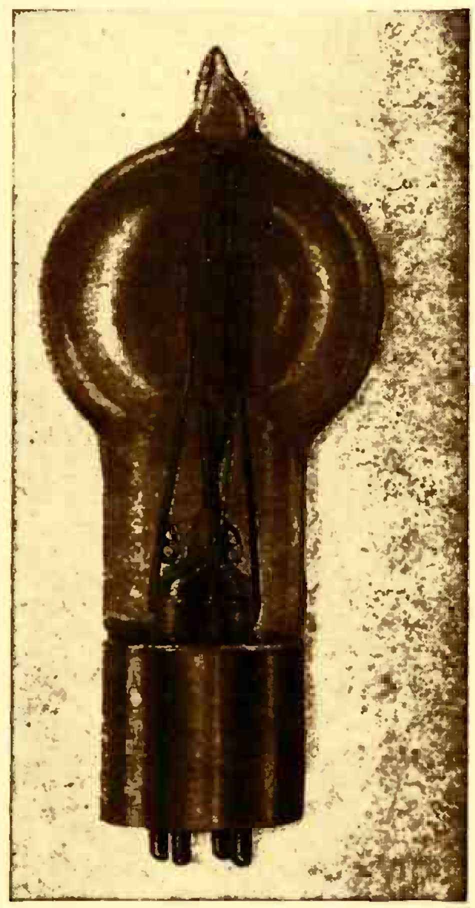
This was the peak of de Forest's success with spark sets. He soon was surpassed in technical ways by Stone's loose-coupled sets, with strictly uniwave transmission, and by the giant Fessenden set installed at the Navy's first high-power station, NAA, at Arlington, Va., with its 500-cycle supply and a rotary synchronous gap.

Navy Vacuum-tube Equipment

De Forest, however, was merely biding his time to go forward to greater successes by a different means. His first crude experiments with a vacuum tube, first as a detector, then as an amplifier, and finally as an oscillator, in time lifted radio to a new era, and his little nickel grid proved to be the electrical lever which would move the radio world. There was a gap between the spark era, with its use of trains of waves, and the later vacuum-tube era, this gap being filled for a time by the continuous-wave Poulsen arc system as developed by the Federal Telegraph Company. Even this intermediate method owed much of its success to de Forest adjuncts. In time, also, the arc passed out of the picture, and the vacuum tube reigned supreme in all fields of radio. Leaving out all matters of controversy, broadly speaking it was de Forest's invention of vacuum-tube control by means of a grid that caused the vacuum tube to become the universal tool for radio in transmitting, receiving, and amplifying.

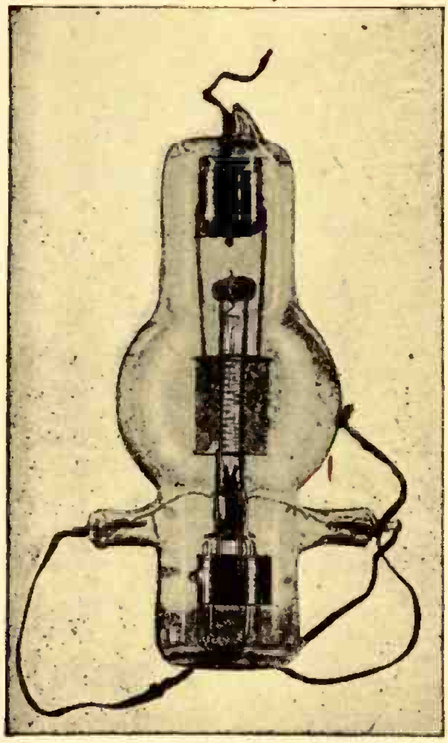
De Forest's first contact with the Navy along these lines was before he had brought forward the grid, however. He made his first Government sale of vacuum tubes in 1906, to the United States Navy, in the form of a complete receiving set fitted with audion detectors, with candelabra base. These were, however, of the two-element type, with plate and filament only. These, as well as the three-element forms which soon followed, bore the name "audion," however.

In 1907 he came closer to the final goal, in that he introduced wireless telephony to the Navy, and with it the three-element audion. In November of that year the famous voyage of "Fighting Bob" Evans' fleet around the world took place. De Forest interested the Navy in having a wireless telephone installed on the



Courtesy Gerald F. J. Tyne

De Forest "Singer Type" tube used by Navy.

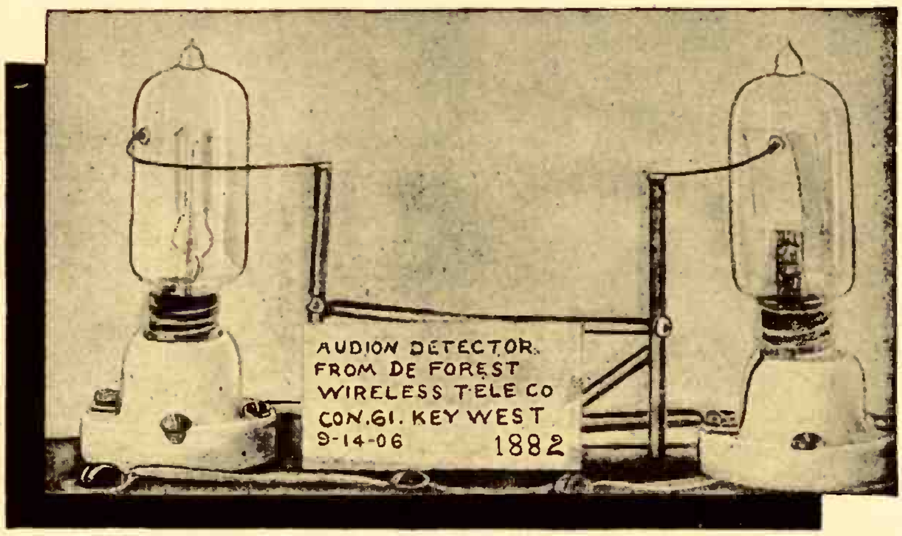


Courtesy Gerald F. J. Tyne
The Type H was a 150-watt transmitting tube.

bridge of the principal vessels in the squadron, so that officer could speak with officer without an operator-intermediary. This idea, which was technically and strategically correct, failed, for several reasons. First, the standard wireless telegraph set and the new telephone could not operate simultaneously, duplex-diplex operation not having been provided nor indeed thought of. Second, the "new-fangled" installation required a technical man to keep it in operation, and in those days such men were operators, not officers. Other difficulties were present, as might be expected in a pioneer installation, so that the idea did not work as well as its deviser had hoped, yet many good results were obtained with it. One of these was the "broadcasting" of phonograph records by then Chief Electrician H. J. Meneratti from the U.S.S. *Ohio* to her sister ships, during many nights of the world voyage. This story alone is most interesting, but space does not permit further description.

Not long after this world cruise, de Forest presented the audion to the Navy's attention for use as a detector, and little by little it became more desired; sales became more frequent. An official accounting made for later court proceedings lists a sale of 1,000 single plate and grid audions at $2.50 each, sold on contract dated January 12, 1914; 500 oxide filament tubes, at $12.50, on October 5, 1916; 1,000 ultraudion and amplifying tubes, double plate and grid, at $4.00, on September 25, 1917. These were not the first, nor the last, nor the total of the sales, but are mentioned to give a general idea of usage and price.

There was, unfortunately, one bone of contention between "Doc"—as de Forest is called lovingly by his friends—and the Government from the beginning; he contended that "a little gas in the tube was a good thing," whereas the Navy said it was not. Both were right! De Forest was in some ways an amateur at heart, and sold his first tubes to amateurs. These eager lads wanted the greatest sensitiveness possible, and were perfectly willing to juggle filament current and plate voltage to obtain it. That such tube conditions did not make for stability bothered them not at all. But it did bother the Navy; each tube had to have the same constants as its mate, so that if a tube burned out during reception of an important message a second could be switched in and used immediately without readjustment. The controversy ended with the Navy specifying such a standard tube, which de Forest either could not or would not make, and so he lost what might have been a very profitable business during World War I. It was appreciated by those in charge that Dr. de Forest had brought audions into the world and to the Navy Department, and that it would have been only right to reward him in the form of orders; but Navy efficiency of course came first.



Courtesy Clark Historical Library
Two of the early pre-grid de Forest audions, each with two plates and filament.

Audion Amplifiers

All of the foregoing refers to the use of the audion as a detector for reception of spark signals. Next in line was de Forest's offer of the audion as an amplifier, destined to become an indispensable element in radio operation. For years previous, various forms of amplifiers, all of the carbon-microphone type, had been tested by the Navy. Not one had proved worth adopting. On November 25, 1912, all this was changed. On this date de Forest sent to the Navy for test a "breadboard" model of a three-stage audion amplifier, the result of his experimentation at the laboratory of the Federal Telegraph Company, Palo Alto, Calif. This was brought to the Arlington station, NAA, by Charles Logwood, Dr de Forest's assistant, and others. Chiefs W. A. Eaton and J. W. Scanlon, and the author, tested it for distance, and also for degree of amplification. Stations hitherto unheard at NAA, especially some on the West Coast, came in readably, even in the daytime. Technical measurements showed an amplification of 4 for the first stage (in terms of "audibility") and a value of 10 for two stages. The third stage "squealed" so that it could not be used. This model, although crude, showed so much promise that de Forest was encouraged to develop it into practical form, and during the ensuing years many purchases were made. In December, 1913, the Radio Telegraph and Telephone Company, one of de Forest's companies, quoted $475 for an amplifier, and that same month a requisition was made by the Navy for ten amplifiers with four relays and bells and two loud-speaking horns. (The relays were of the Weston galvanometer type, and the bells showed that de Forest had at last caught up with Slaby's coherer and bell of 1903!)

The third development of de Forest which came into later major adoption by the U. S. Navy was his oscillating audion, particularly when associated with a receiver and used for heterodyne reception. The history of this is indeed involved.

The Navy first became interested

in heterodyne reception during 1912, when the 100-kw Fessenden spark set at Arlington and a 30-kw Poulsen arc temporarily installed at the same station by C. F. Elwell were being given a long-distance test by reception on the U.S.S. *Salem.* The spark set, of course, developed discontinuous waves; the arc was a continuous-wave generator. The Fessenden company installed on the ship the first heterodyne receiving system known to the Navy. It was used to compare the distant spark and arc sets.

The Oscillating Detector

Up to that time the arc had been copied by means of a rotary *ticker,* a fine wire pressing on a rotating drum. Such signals were rustling, "shushy." Spark signals, however, when received on an electrolytic or crystal detector, gave a clear, musical sound, especially when the sending station was powered by a 500-cycle alternator, as was the case at NAA. But with the heterodyne method of reception, all was reversed; the spark signals lost their musical nature, while those from the arc became musical indeed, and with the added advantage that the note could be varied at will by the receiving operator to suit his own ear. To this may be added the fact that the heterodyne signals from the 30-kw arc were heard much farther than any signals from the giant 100-kw spark.

But all was not perfect, despite these advantages. Heterodyning was performed, on the *Salem,* by mixing the incoming signals with continuous waves produced by a local oscillator. This latter was a small arc, though not so very small, at that! Moreover, the arc was highly temperamental, and worked only when it wanted to, as the writer well remembers. With the Navy's insistance on dependability and uninterrupted communication, such a device was not usable, even though desirable. What, then, could be substituted for the arc as a generator of c.w.?

As of course everyone knows today, the answer was "an oscillating audion." But, due to reasons which will not be discussed here, no one had at that time brought such a device to the Bureau for test. The writer had heard of such a means, through records shown to him by a company then making tests at Arlington, and he at once made his own tests. He used home-wound feed-back coils, and even went so far as to coin a name for these: "tickler coils"—because they "tickled the audion and made it oscillate." But since no commercial form seemed to be available for such use, the Navy's work was experimental only.

In April, 1914, the de Forest company wrote to the Navy, stating that it was about to display a new form of receiver at an exhibition sponsored by the Bureau of Standards, and asking that a representative of the Navy Department be present. "This includes the use of the audion as a detector of undamped oscillations," the letter said. This was enough to cause immediate and thorough inspection, and it was found that these receivers fitted exactly the Navy's desire for c.w. reception. It was also said that these receivers "did not include feed-back coils, hence did not violate existing patents." A number of sets were at once purchased from de Forest, and these so-called "Ultraudion" receivers—in which, it was learned later, feedback action did exist, though in a form of capacity coupling—made it possible for the Navy to make fullest use of its arc transmitters, and in a short time to provide a world-wide chain of radio communication.

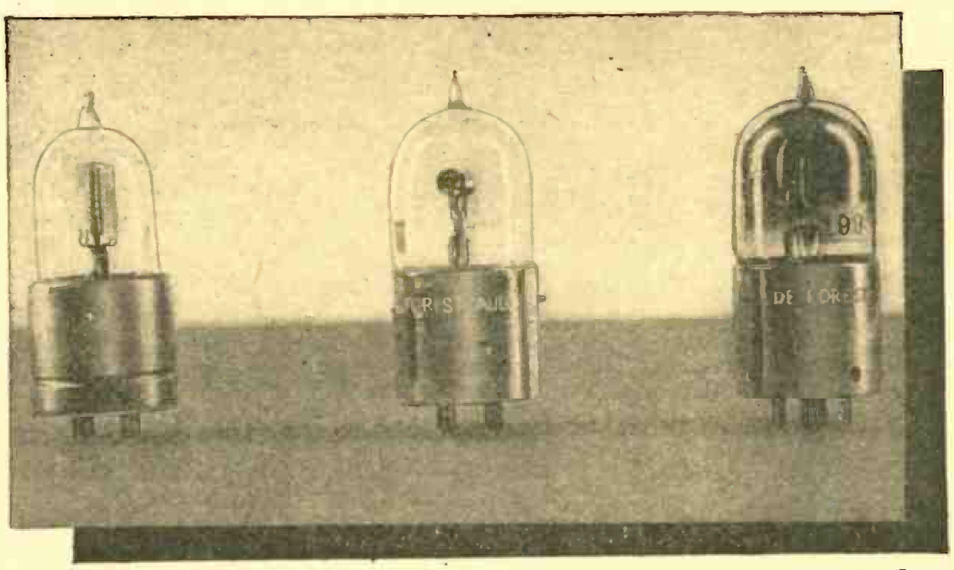
Had some other company brought to the Navy's attention a coil-coupled form of feedback, the writer can say that as far as he was concerned he would certainly have tested it and recommended its adoption; but no one did. That de Forest, who was already recognized as the father of the audion and of the amplifier, should now have brought a third feature of the little tube into play, by using it as an oscillator and thereby making heterodyne reception practicable, seemed but another logical development of this versatile inventor.

Audion Transmitting Tubes

But there was yet another offering which he had to make to the U. S. Navy and to the world. That was the development of the tiny receiving tubes into larger and larger ones, generators of electric waves which in time became the source of high-frequency power for all forms of transmitters. De Forest sold sets of this nature to the Government, particularly for airplane use, but the flood of business arising from the war led to the advent of many other manufacturers, and de Forest by no means reaped a rich reward for what was later proven to have been legally his offspring.

Of the later work of de Forest in pioneer broadcasting, of his untiring efforts along other lines such as motion pictures, television, diathermy, and the like, this article does not treat. His invention of grid control of the vacuum tube was the tiny forerunner of a new era of radio communication, replacing other too ponderous types of continuous-wave production by smaller, more controllable devices, in the form of small and large vacuum tubes. He was first to produce a successful type of amplifier, long the goal of inventors. His success in setting up persistent oscillations by means of the vacuum tube made the heterodyne reception of radio telegraphy possible, and later these tubes, enlarged, supplied the other end of the chain by becoming the creative part of the distant transmitters themselves. On the basis of successful achievement alone, Dr. "Aladdin" de Forest, as he should have been called, deserves a world's praise in these electronic days, and he in turn undoubtedly will admit that much of his success in those earlier years was due to the pressure of the needs of the United States Navy.

The foregoing represents the author's memories of his personal experiences, and is not intended to refer in any way to the possible viewpoint of any other person or organization.



Courtesy Gerald F. J. Tyne

Two Type 20's and one VT-21, a tube used by the Government during the first World War.

AN EARLY RADIOPHONE

THE MODERN reader has difficulty in fully appreciating the impact of some of de Forest's earlier discoveries on the technical world of the time. So obvious are their effects today that it is difficult indeed to realize that they were by no means so to the wireless authorities of the 1900's.

Readers can get a fair idea of how the radiophone was looked upon in those days from the following article, reproduced verbatim from MODERN ELECTRICS, August, 1908:

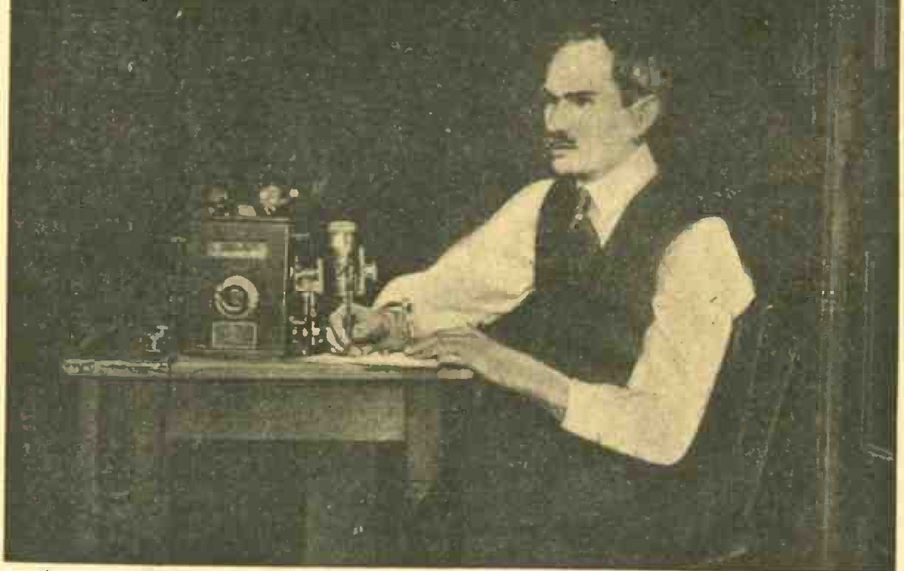


Fig. 2—A photograph of de Forest at one of the instruments described in this article.

The new art of wireless telephony has advanced to such a stage that the U. S. Navy has lately equipped 32 war vessels with complete sets. This point alone is a guarantee of the practicability of the wireless telephone, as it is a well known fact that the government does not adopt any apparatus until its utility has been proven.

The sets were sold under a contract to hold unbroken communication up to a distance of five miles regardless of fogs or atmospheric disturbances. This distance, however, has been doubled several times, and the latest records show that a distance of 26 miles has been covered, the messages being picked up by the receiving end of a wireless telegraph set which no doubt could have been farther extended by the use of the special telephone receiving sets as employed with the telephone.

The fleet which sailed around the Horn to the Pacific was equipped with complete sets. Admiral Evans could keep in constant communication with any of the ships—directing the movements of the whole fleet from one point which may sound the death knell of the old wig-wag system of signaling used for an indefinite period by the navy.

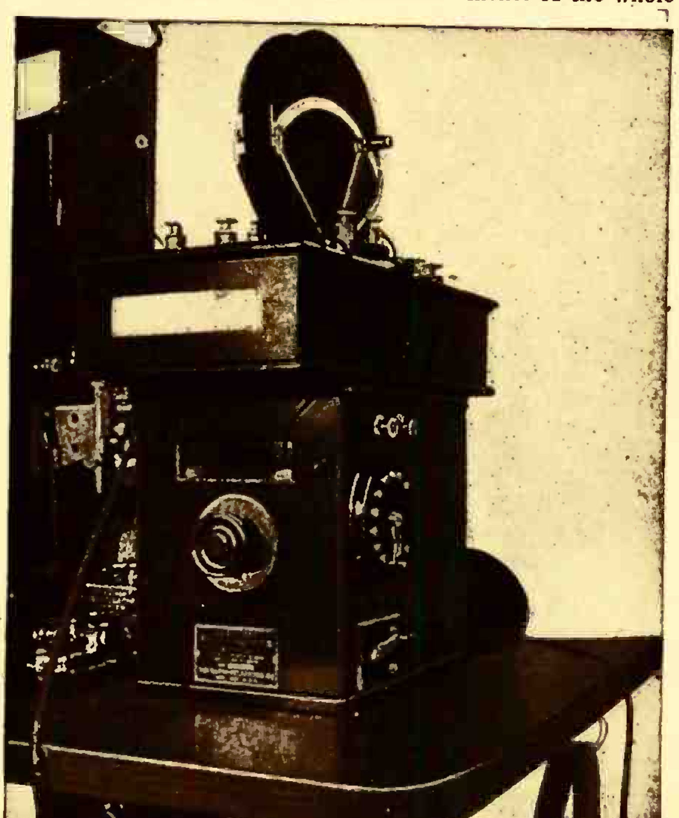


Fig. 4—Close-up of receiving apparatus and tuning equipment.

The naval attachés are particularly proud of the fact that the U. S. navy is the only one in the world utilizing this means of communication but already foreign ambassadors are negotiating with the makers for like sets.

In operation the wireless telephone is very simple, and depends on the same principle as telegraphy, that is, the generation of Hertzian waves that pass through space 186,000 miles per second. While the principle is the same, yet the actual working is vastly different, as was soon realized by the numerous investigators who took up the subject with the introduction of wireless telegraphy. In telegraphy the transformer or transforming device is supplied by alternating current with periodic break or direct current with mechanical break. In either case the emitted wave is periodic. This, however, would not answer for wireless telephony, as the break would destroy all properties of speech.

The problem now was to provide some means for generation of a continuous wave current and impress thereon the modulations of the human voice which would possess the same qualities when caught at the distant receiving end and reproduce the spoken words.

The generation of such waves was made possible by the use of Duddell's arrangement, which is identical with the wireless telephone of the day with the addition of a few changes.

The circuits of the de Forest sending and receiving ends as shown in the May issue are repeated here for sake of clearness.

The transmitting set consists of an ordinary arc lamp (oscillator) burned in the flame of an alcohol lamp from a 220-volt circuit, which sets up oscillations. The latter flow through the condenser and primary of transformer, exciting the secondary, which has one terminal leading to the ground through a telephone transmitter, and aerial wire.

It can now be understood that the wave current in flowing through the transmitter to the ground and aerial wire will be changed to the same proportion as the voice which falls against the diaphragm of the transmitter. A certain portion of this wave is caught by the antenna of the receiving end, which flows through the primary of a transformer set to the same wave length; passing the secondary, it flows through the capacity condensers to the "Audion"; here it produces a like change in the ionized gases which changes the current from a local battery flowing through a telephone receiver, resulting in the spoken words increased in sound to a large extent.

Here we have the complete de Forest system, which of course required a considerable amount of ingenuity and work on the part of Dr. de Forest to bring the apparatus to its present stage of perfection.

In the June issue of this magazine was described a "Flame Audion" which works on the same theory as the one employed in wireless telephony. The "Audion" used by de Forest is an ordinary incandescent lamp with a platinum grid and wing sealed in a lamp bulb, as shown in the diagram. The "Flame Audion" has the platinum contacts inserted in the flame impregnated with certain salts.

In Fig. 3 is shown a set designed for portable use, and is packed ready for transportation. [It was not possible to reproduce this figure.—*Editor*].

With this set communication can be established in a short while, as portable and easily handled aerial arrangements are being provided for this purpose.

To the left is the transmitter, consisting of the high tension coil placed in case with telephone transmitter mounted on an arc lamp in the back. The telegraph key and a device known as the "chopper," which resembles the ordinary buzzer, are shown in the front. The "chopper" is inserted in the aerial wire, and when the key is pressed operates the wireless telegraph apparatus, for calling, etc.

The complete receiving set is shown in Fig. 4. Here we have the "pancake" syntonizer on top, adjustable condenser, tuning arrangement, and reserve "audion" for use in emergency.

In Fig. 2 is shown Dr. de Forest at the instrument, the audion is seen between his hands.

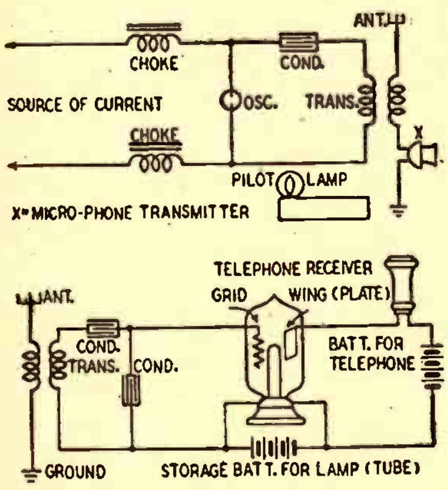


Fig. 1—Transmitter and receiver schematics. These were typical of early de Forest equipment. Oscillator symbol represents a carbon arc in its pot. The telephone receiver shows strong influences from the 75-ohm line type, indeed often used with radios of that period.

FIRST RADIO ASSOCIATION

By Hugo Gernsback

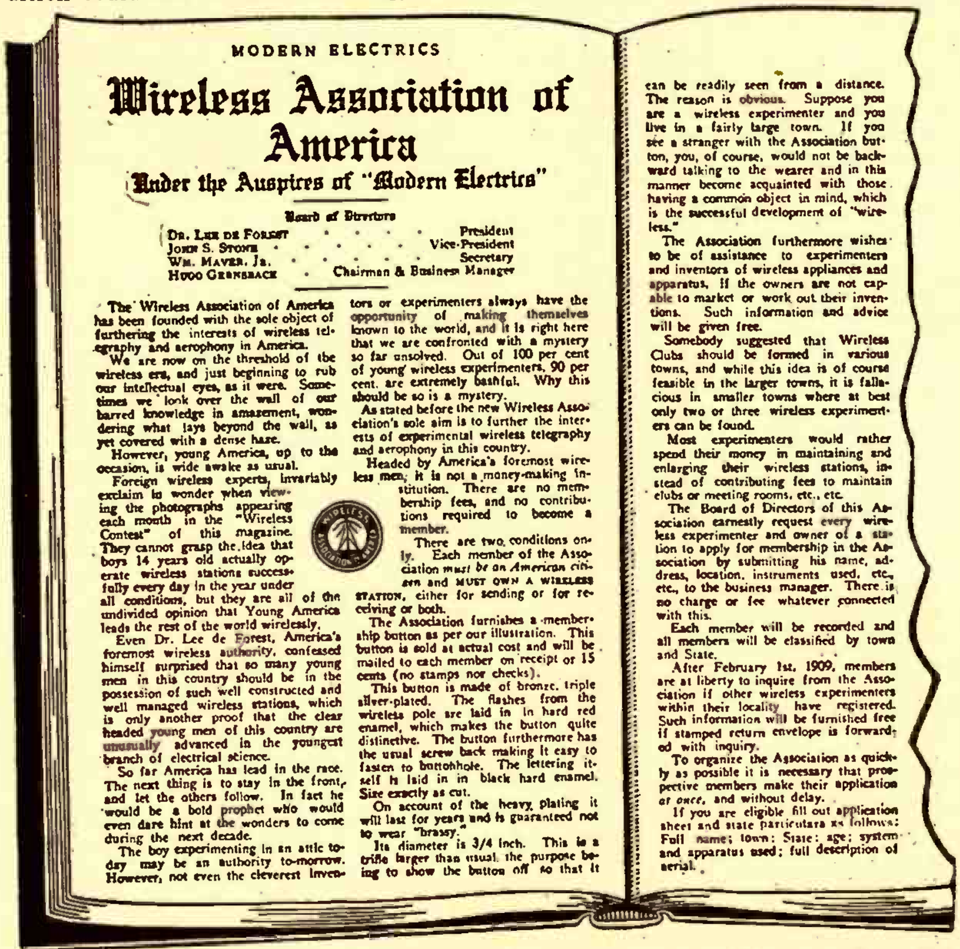
SOME TIME during the early fall of 1908, when wireless was booming, the writer became convinced that it was necessary to band together the wireless amateurs into a national body. Accordingly, he set out to launch an association. The chief reason at that time was to organize a national body to ward off adverse legislation against the wireless amateur.

In those heydays there was no radio law. Anyone who had a transmitter just helped himself to whatever wavelength he took a fancy. Obviously, such a condition could not continue for long, and already there were rumbles that Congress intended to do something about it.

Everyone feared that the amateur might be put off the air entirely. It was the writer's thought that if a national body of amateurs existed, they could make their voice felt in Washington, which indeed they did when the first radio law was enacted in 1912.

To give the proposed association a solid standing the writer, in October, 1908, wrote a number of letters to well known radio personalities. Even in these early days Dr. Lee de Forest was easily the outstanding radio figure in this country. For that reason the writer proposed to de Forest to become the first president of the first national wireless association. Late in October, 1908, Dr. de Forest accepted. The other founders, all well-known radio personages, were John S. Stone of radio fame, who became Vice President; William Maver, Jr., author of one of the first radio engineering books, was Secretary; the writer was Chairman and Business Manager.

The league finally was organized in November, 1908. The first announcement of the new body "The Wireless Association of America" appeared in the writer's publication MODERN ELECTRICS, in the January, 1909, issue, which was on the newsstands in December, 1908. This was the first national radio association anywhere in the world.



MODERN ELECTRICS

Wireless Association of America

Under the Auspices of "Modern Electrics"

Board of Directors

DR. LEE DE FOREST	President
JOHN S. STONE	Vice-President
WM. MAVER, JR.	Secretary
HUGO GERNSBACK	Chairman & Business Manager

The Wireless Association of America has been founded with the sole object of furthering the interests of wireless telegraphy and aerophony in America.

We are now on the threshold of the wireless era, and just beginning to rub our intellectual eyes, as it were. Sometimes we look over the wall of our barred knowledge in amazement, wondering what lays beyond the wall, as yet covered with a dense haze.

However, young America, up to the occasion, is wide awake as usual.

Foreign wireless experts, invariably exclaim in wonder when viewing the photographs appearing each month in the "Wireless Contest" of this magazine. They cannot grasp the idea that boys 14 years old actually operate wireless stations successfully every day in the year under all conditions, but they are all of the undivided opinion that Young America leads the rest of the world wirelessly.

Even Dr. Lee de Forest, America's foremost wireless authority, confessed himself surprised that so many young men in this country should be in the possession of such well constructed and well managed wireless stations, which is only another proof that the clear headed young men of this country are unusually advanced in the youngest branch of electrical science.

So far America has lead in the race. The next thing is to stay in the front, and let the others follow. In fact he would be a bold prophet who would even dare hint at the wonders to come during the next decade.

The boy experimenting in an attic today may be an authority to-morrow. However, not even the cleverest inventors or experimenters always have the opportunity of making themselves known to the world, and it is right here that we are confronted with a mystery so far unsolved. Out of 100 per cent of young wireless experimenters, 90 per cent. are extremely bashful. Why this should be so is a mystery.

As stated before the new Wireless Association's sole aim is to further the interests of experimental wireless telegraphy and aerophony in this country.

Headed by America's foremost wireless men, it is not a money-making institution. There are no membership fees, and no contributions required to become a member.

There are two conditions only. Each member of the Association *must be an American citizen* and MUST OWN A WIRELESS STATION, either for sending or for receiving or both.

The Association furnishes a membership button as per our illustration. This button is sold at actual cost and will be mailed to each member on receipt of 15 cents (no stamps nor checks).

This button is made of bronze, triple silver-plated. The flashes from the wireless pole are laid in in hard red enamel, which makes the button quite distinctive. The button furthermore has the usual screw back making it easy to fasten to buttonhole. The lettering itself is laid in in black hard enamel. Size exactly as cut.

On account of the heavy plating it will last for years and is guaranteed not to wear "brassy."

Its diameter is 3/4 inch. This is a trifle larger than usual, the purpose being to show the button off so that it can be readily seen from a distance. The reason is obvious. Suppose you are a wireless experimenter and you live in a fairly large town. If you see a stranger with the Association button, you, of course, would not be backward talking to the wearer and in this manner become acquainted with those having a common object in mind, which is the successful development of "wireless."

The Association furthermore wishes to be of assistance to experimenters and inventors of wireless appliances and apparatus. If the owners are not capable to market or work out their inventions. Such information and advice will be given free.

Somebody suggested that Wireless Clubs should be formed in various towns, and while this idea is of course feasible in the larger towns, it is fallacious in smaller towns where at best only two or three wireless experimenters can be found.

Most experimenters would rather spend their money in maintaining and enlarging their wireless stations, instead of contributing fees to maintain clubs or meeting rooms, etc., etc.

The Board of Directors of this Association earnestly request every wireless experimenter and owner of a station to apply for membership in the Association by submitting his name, address, location, instruments used, etc., etc., to the business manager. There is no charge or fee whatever connected with this.

Each member will be recorded and all members will be classified by town and State.

After February 1st, 1909, members are at liberty to inquire from the Association if other wireless experimenters within their locality have registered. Such information will be furnished free if stamped return envelope is forwarded with inquiry.

To organize the Association as quickly as possible it is necessary that prospective members make their application *at once*, and without delay.

If you are eligible fill out application sheet and state particulars as follows: Full name; town; State; age; system and apparatus used; full description of aerial.

The above is a reproduction from the January, 1909, issue of MODERN ELECTRICS. Illustration in the center is the first radio association insignia: a lapel button of that time.

By the end of 1912, the Association had some 14,000 members scattered all over the country and each member was given a lapel button to wear.

The Association also printed a book with the names and addresses of the members. Its title was: *The Wireless Bluebook;* it also was the first radio association membership book in print.

It is significant that Dr. Lee de Forest, who has so many firsts attached to his name should also have been the first President of the first Wireless Association.

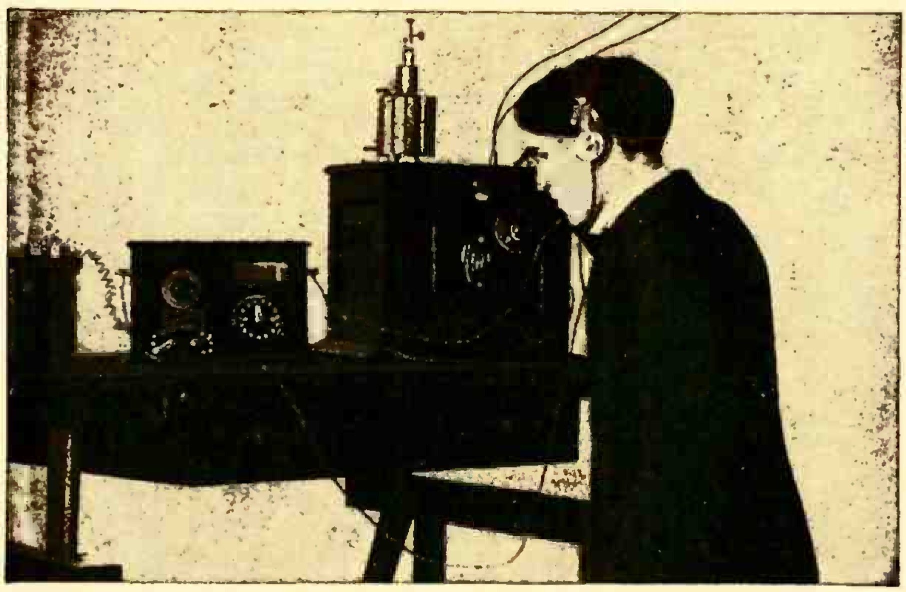
(Continued on page 40)

FIRST PHONE BROADCAST

By Frank E. Butler

THE INVENTION of the three-element vacuum tube by Dr. Lee de Forest in 1906-7 met with foggy and apathetic recognition instead of being welcomed with open arms and appreciated by the electrical industry and the government.

The U. S. Navy Department flatly rejected the first audion tube receiver as being impractical and unreliable. A storage battery, officials said, was subject to constant recharge with subsequent possibility of losing part of an incoming message; battery fluid might spill during action at sea, thus ruining the deck of the operator's cabin. Besides, it was too high in initial price and the renewal cost of bulbs, compared to the low cost and reliability of detectors then in use.



The author, Frank Butler, stands in front of the equipment which made the first broadcast.

The Western Union and Postal Telegraph Companies, likewise the Bell Telephone System, frowned upon the idea. Long distance telephony, though greatly desired, was then unborn because mechanical relays were insufficient for the assigned task of boosting. Western Electric was concerned only in making instruments for the telephone company. George Westinghouse was interested in manufacturing airbrakes for railroad trains; Thomas Edison and the Victor Talking Machine Company in turning out phonographs. The General Electric Company specialized in motors, dynamos, and other small electrical parts. None of them were professionally interested in de Forest's idle dreams of a new wireless world—and all this happened 12 years before the Radio Corporation of America was thought of.

In a word there was no place nor persons to turn to for counsel, encouragement, or assistance.

De Forest, far from discouraged, loomed up at the lab with a changed mental attitude, fresh for another round, and indicated that the fight was not over. His first suggestion was to chuck the wireless receiver under the table. He was through with it for awhile. He announced that his new idea was to develop a wireless telephone, and explained that this thought had been in his mind for some time while he was busy with other matters.

Fortunately, the Parker Building in New York City, had both 110 and 220 volts d.c. It was this latter voltage de Forest chose for experiment with a "singing arc." Among his first tests he found that the standard wireless telegraph transmission circuit was not adaptable to the arc principle, therefore the entire circuit had to be revamped and tested before it could function as a generator of the continuous, undamped, high-frequency waves which were required. Many experiments were conducted to determine the correct method of surrounding the arc with a gaseous atmosphere and the proper kinds of electrodes to employ. An alcohol lamp was decided upon to supply the required gas from denatured fumes within a chimney made of thin fire-clay through which two electrodes extended. These were located above or within the hot alcohol flame, in a chimney area about 1½-inches in diameter. The chimney was open at the top and the strong, obnoxious odors emanating from the lamp were almost unbearable.

It should be borne in mind that the audion first was produced as a reception device. At the time of the wireless telephone tests de Forest was unaware of the oscillating qualities of the tube and its capacity to act as a transmitter.

Finally all was in readiness for the initial test of talking across the room. A discarded shipping box salvaged from a rug concern on a lower floor provided the workbench upon which rested our hopes, represented by a breadboard hookup of a jumbled mess of tubular cardboard boxes mounted with wires, an upright standard or rod holding a Blake carbon-button telephone transmitter, an alcohol lamp with chimney, and other apparatus. On the opposite side of the room the one and only audion receiver, "Old Grand-dad"—which had been retrieved from underneath the table—rested majestically on the drafting board, the only piece of real furniture in the lab. The distance of this historic test was less than ten feet.

Dr. de Forest, coatless and in a serious mood, stood before the transmitter, breathing the foul fumes of burnt alcohol, carefully changing from one adjustment to the other as he spoke into the microphone, drawling monotonously:

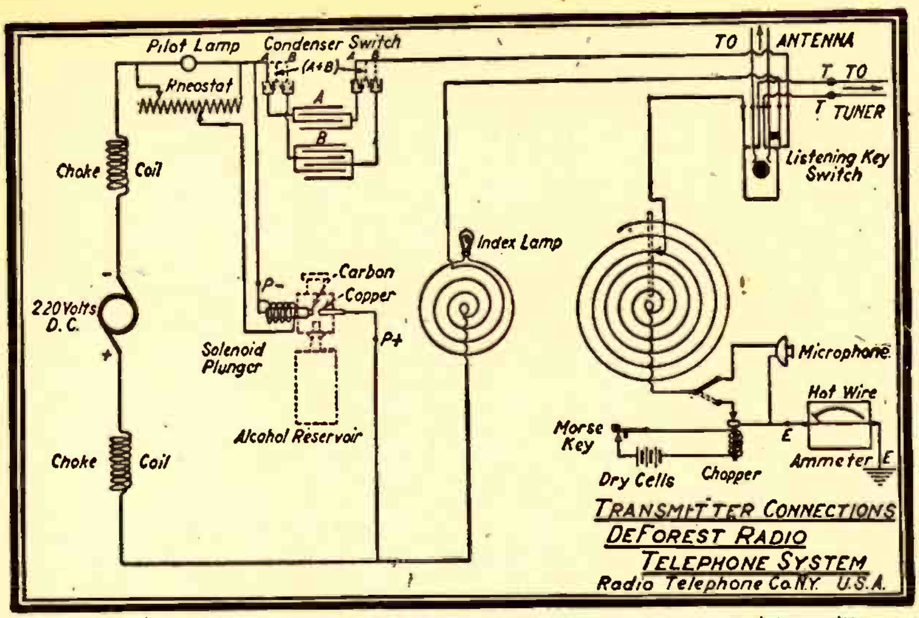
"One, two, three, four—Can you hear me?"

On the other side of the room, with headphone pressed tightly to my ear I listened, as I too changed tuning adjustments. In my uncovered ear I could easily hear de Forest's voice, but the headphone on the other ear was unresponsive. Just then a connecting wire broke from its hurriedly twisted joint and fell at de Forest's feet. Stooping to pick it up, his face accidentally touched the metal frame of the telephone transmitter. He jerked away and exclaimed:

"That's hot! No wonder the thing won't work. Now, I know what's wrong—those granules in that carbon button are packed together. The phone circuit is shorted!"

He picked up a screwdriver and as he resumed his singsong monologue, he struck the metal frame with the handle, saying:

"One, two"—*bang!* The blow instantly dislodged the carbon impaction and permitted the word "three" to go through his jumble of wires and leap the intervening gap of space between



Schematic of de Forest radiophone, the commercial version of the original transmitter.

us, the "three" being clearly audible in the headphone on my left ear.

Space conquered by wireless telephony!

At *that* moment, in the early summer of 1907, *radio* broadcasting was born!

In the dazzling light of current achievements it is far more difficult to recapture the immediate simplicity and importance of this occasion than to rhapsodize on its measureless portents. Commonplace ideas today—worldwide radio communication, talking pictures, radio, and electronics—all were unborn. The problem then was to transmit the voice only a matter of inches.

"Let's rig up an antenna from that 30-foot flagpole on the roof and send this stuff out over the air," said de Forest. "Guess we'd better try it with music, though. We'll save our words and let any listener guess who's doing it."

I was sent out to find a second-hand talking machine and returned shortly with a used phonograph and a single record—one side of which was "The Anvil Chorus" from *Il Trovatore*.

The Brooklyn Navy Yard was about four miles away. Just inside its Sands Street entrance stood a 150-foot pole, surmounted by a crossarm from which hung a dozen aerial wires leading into a one-room wireless shack at its base. This shack housed the Yard's first wireless telegraph station, which was equipped with a Slaby-Arco outfit of German design.

At the time this wireless telephone test was being made by Dr. de Forest, three Navy operators were on duty at this station—G. S. Davis, George F. Smith, and Arthur F. Wallis. Young Davis was on watch at that historic moment. With headphones on his ears he was vainly trying to intercept and copy a wireless message from a ship at sea. The signals were coming in very faintly. Nervously he fidgeted about as he sat on the edge of his chair, leaning forward and straining to hear the scarcely audible signals which were badly chewed up by rifts of uncontrollable static. The other two stood nearby, unable to give any assistance. Finally, with patience exhausted, Davis exclaimed:

"I wish there'd be something else on the air besides that damned static—!"

His wish was granted sooner than he expected, for at that moment the whispering, spasmodic dots and dashes were unceremoniously interrupted by mysterious sounds that were unmistakingly those of a "blacksmith hammering blows on his anvil with a sledge." Davis turned pale. He thought for a wild moment that his receiver was haunted, he later explained. Before he could utter a word, strains of music followed—a continuing portion of "The Anvil Chorus" record now being reproduced by de Forest in the Parker Building.

Disbelieving his senses, Davis was both scared and dumbfounded. No wireless operator had ever before heard musical sounds come through headphones. Frantically he called to his companions:

"Hey, fellers! Listen! Come here quick! Music, yeah, *music*—plain! Come quick—*it's angels I guess.*"

"Aw you're nutty, Davis," exclaimed Wallis. "Here, gimme those phones." He snatched the headpiece from Davis's head. "Let me listen to whatever you're talking about!"

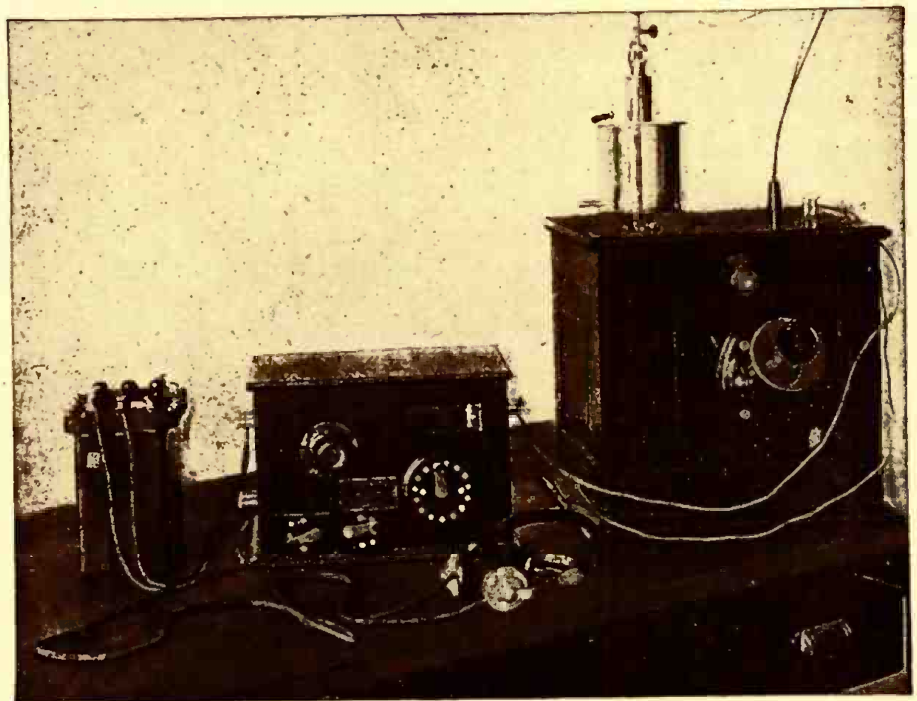
"God! You're right!" exclaimed Wallis, his tone of ridicule changing to one of amazement as he listened intently. "I never heard of anything like that before. Of course it's music—but it can't be angels, because how'd they be playing the 'Anvil Chorus' in Heaven, and that's surely what that music is. Here Smith—you listen! What do you think?"

Smith had been impatiently standing by, anxiously awaiting the chance to hear. He adjusted the phones to his ears just in time to hear the last few notes of music, and then a man's voice broke in and said:

"One" — boom — "Two" — boom — "Three" — boom — "Four" — boom — as de Forest wielded the screwdriver against the Blake transmitter between words to dislodge its granules of fused carbon. Smith, startled because he mistook the thumping "booms" for something else, took off the headphones and said to Davis and Wallis excitedly:

"I heard something too, but it wasn't angels singing or blacksmith's pounding. What I heard was *gunfire*. It sounded like an admiral's salute, only there weren't that many shots. All I heard was four. I know—I heard a man count 'em just before each shot."

The three operators, impressed with the uncanniness of hearing mysterious



Courtesy Clark Historical Library

Early de Forest radiophone equipment, type B arc transmitter and audion receiver.

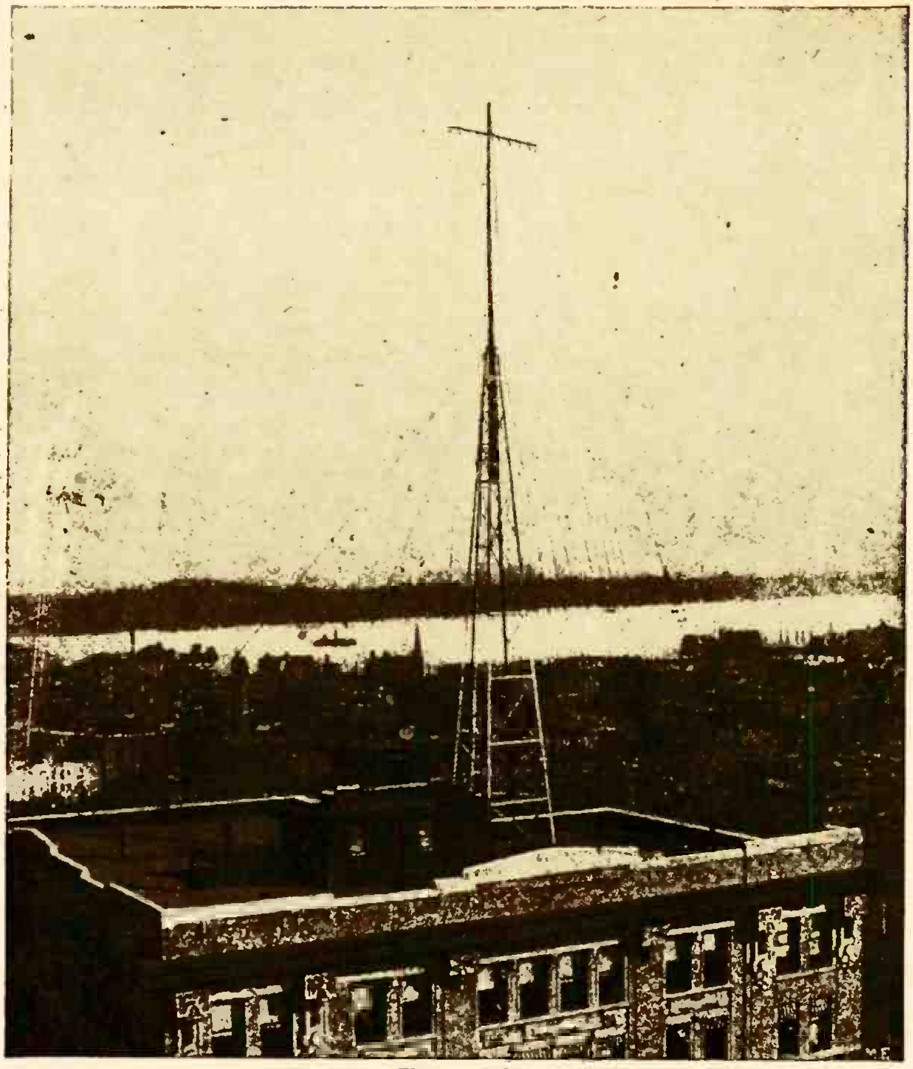


Photo reproduced from Modern Electrics, *Oct. 1908 issue.*
This "Aerophone Tower" was erected by de Forest's *Radio Telephone Co.* in 1908, on the Terminal Building, 42nd Street and Park Avenue, New York City. Intended for use in telephone communication with ships, it was 125 feet high and supported an antenna of eight phosphor-bronze wires, which ran from the top of the mast down to the edge of the building's roof.

music and voices coming through space by wireless, telephoned to New York newspapers and told of their experience. Stories were published around which reporters wove mystery as to through whom, where, and how such a new kind of wireless had come into being. As a result of this publicity the *Literary Digest* wanted a special story of the invention. A reporter and photographer called for particulars. De Forest gave them the details and they prepared to take a photograph of all the apparatus, including the original audion and its seven-plate Witherbee storage battery as well as the recently assembled wireless telephone transmitter which was now encased in a mahogany cabinet on top of which was the alcohol lamp. At the moment when all was in readiness for the camera shot I came in the door, just as the reporter said:

"I think if one of you men stood in front of these instruments it would be more appropriate and descriptive of what it is."

"Go ahead, Frank," said de Forest promptly, "You stand up in front of them—you've got your coat on."

Doubtless he did not realize at the time the tremendous historic importance that photograph would one day assume, else he instead would justly and rightfully have stepped up in my place even though he was coatless. As it was, that picture — herewith reproduced — appeared in the June 15, 1907, issue of the *Literary Digest*. A few months afterward a disastrous fire destroyed the Parker Building, completely consuming all of de Forest's possessions, including his priceless records, and all the original audions and wireless telephone apparatus. Thus this picture represents the only physical evidence in existence of that basic equipment from whence grew radio broadcasting and all forms of electronic speech.

FIRST RADIO ASSOCIATION

(Continued from page 37)

More important than this is the fact that the Father of Radio clearly saw the great future of radio, even at that early date, and was willing to lend his name to radio amateurism then. Dr. de Forest proved himself a most staunch friend of the amateur, because it was he also who, in those pioneering days, set aside many of his Audions which were sold to the wireless amateurs.

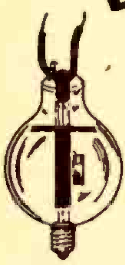
The following description of the *Wireless Association of America* was written by radio historian Clinton de Soto, in his book *Two Hundred Meters and Down*, the Story of Amateur Radio, published by the A.R.R.L.

"*The Wireless Association of America* was a child of *Hugo Gernsback*, publisher of Modern Electrics. After the first few months of its existence, Gernsback announced a membership totalling 3200. By November, 1910, he claimed that this number had jumped to 10,000. It was easy to recruit members for such an organization; there were no dues and no obligations. Youthful electrical experimenters signed up in swarms, attracted by the famous names in the honorary membership group and the ease of becoming a member. The membership represented a fairly accurate index of national interest in radio, although not, of course, of the number of active transmitters. Even so, the number of worthwhile amateur stations on the air had, according to conservative observers, increased from perhaps one hundred and fifty in 1905 to five or six hundred. The number of small spark coils in use was several times that figure.

"In early 1910 the first *Wireless Blue Book* of the Association appeared dated 1909. It listed ninety U.S. amateur stations who were members of the Association together with the call letters used, approximate wavelength in meters, and the spark length of the induction coil. Stations were listed in the following states: Massachusetts, New York, New Jersey, North Carolina, Missouri, California, Texas, Rhode Island, Oregon, Illinois, Ohio, Pennsylvania, Connecticut, Florida, Indiana, West Virginia, Montana, Washington, Minnesota, Wisconsin and Maine. Wavelengths ranged from 32 to 950 meters. The average spark gaps were from ½ to 3 inches. Two stations had the exceptional length of 10 and 14 inches, respectively.

"The second *Blue Book* appeared June 1, 1910. Meanwhile the number of copies of Modern Electrics printed had increased from the initial 2000 to 30,000. *The Wireless Association of America* continued to send out more and more gaudy membership certificates, and the cumulative numbers on the membership rolls mounted higher and higher."

Radio Inventions of Lee de Forest. . . . . By Fred Shunaman



THE FAME of de Forest as the inventor of radio's most fundamental component has obscured his important work in the radio field as a whole. Many well-informed persons are not aware that he was the inventor of the transformer-operated spark transmitter, the quenched gap used on many shipboard installations till 1940, and the metal radio tube. A few more know that he holds the original patent on regeneration and that he was the inventor of the grid leak. His 1903 patents on r.f. transmission lines cover practices not fully put into use till two or three years ago. Dozens of other patents cover useful improvements in the radio art, or point the way to further progress in radio invention.

De Forest's radio patents date back at least as far as 1902, when he was working on an early type of detector he called a *responder*. Opposite in action to the coherer, it consisted of two metal plugs sealed in a glass tube with a "suitable" solution between them. It was connected in a local battery circuit, as well as to the antenna system. "Little trees and branches" of metal were built up between the two plugs by electrolytic action, bridging the gap and reducing the resistance of the circuit. A signal on the antenna broke down these little bridges, raising the resistance of the circuit.

De Forest called his detector an anti-coherer, and abandoned it only to work with the long series of "heat detectors" which culminated in the audion.

Transmission Lines

Startlingly modern are the antenna feed-line systems described in Patent No. 730,246, filed March 8, 1902, and granted June 9, 1903. Fig. 1-a shows a quarter-wave vertical antenna A and ground G, with a parallel-wire feed-line, BB' running to the responder or detector R. Bridges CC connect the lines together at half-wave intervals, to short out signals of unwanted frequencies. The broken line D indicates the voltage wave along the line and signs indicate the polarity. Fig. 1-b is a co-axial cable version of the same system. Twisted pair is shown in Fig 1-c. Standing waves were expected on the twisted pair, and bridges C are shown. MM are choke coils and Q a telephone. A local battery N is used with the Responder.

The year 1902 saw de Forest busy on other important inventions. Among these was a metal-oxide detector, Patent No. 770,228. Two steel needles, C in Fig. 2, are held by a spring against two aluminum pins, DD. Means for adjusting the spring tension is provided, and the effect of the oxide coating on the aluminum is specifically mentioned, though it is stated that other metals may be used.

Two important patent applications were filed in June, 1903. One of these was the transformer-operated spark transmitter (Patent No. 749,435), shown in Fig. 3. Induction coils with their vibrators and low-voltage contact points were troublesome and tended to set a ceiling on transmitter power. As shown in Fig. 3, a gas-engine-driven alternator G supplied current to a low-voltage 1-to-1-ratio transformer T. A key C was placed between this transformer and high-voltage transformer T1. Choke coils K prevented r.f. surges from backing into the low-frequency lines. The oscillating circuit consisted of gap S, capacitors L, and antenna and ground A and E.

This invention made the spark transmitter a reliable and powerful instrument, and induction coils disappeared except in low-powered experimental apparatus.

The second invention of June,

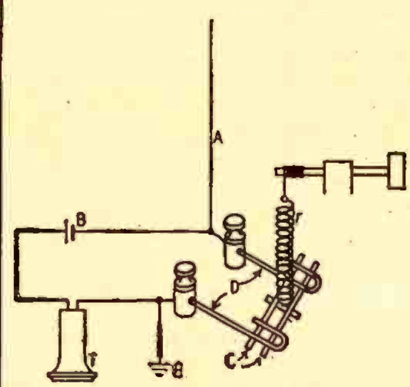


Fig. 2—Early metal-oxide radio detector.

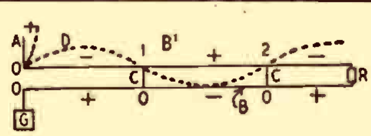


Fig. 1-a—Antenna and transmission line.

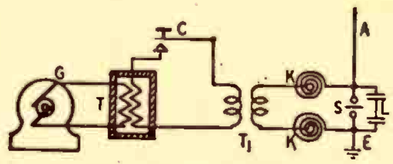


Fig. 3—Alternating-current transmitter.

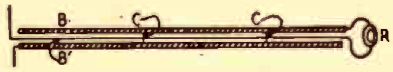


Fig. 1-b—Same as above with co-ax leads.

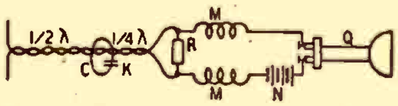


Fig. 1-c—Twisted pair was new in 1902.

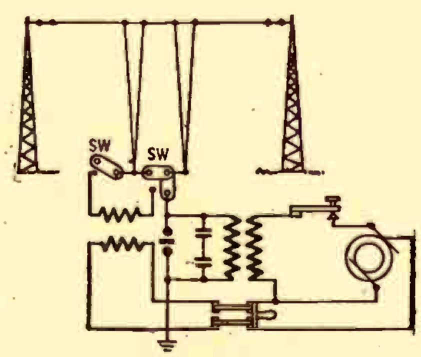


Fig. 4—Device for ice-freeing antennas.

1903, was a device for clearing ice from antennas, Patent No. 750,181. As shown in Fig. 4, this was a method of passing a high current at low voltage through part of the antenna, thereby heating it and melting off the ice. Switches connect either the transmitter or the ice-melting equipment to the antenna, paralleling the lead-ins to the spark gap and separating them across the low-voltage transformer secondary.

Simultaneous Operation

Break-in operation of wireless stations was another of de Forest's June, 1903, patents (No. 749,434). Two aerials were to be used, connected to two motor-driven commutators on the same shaft. Transmitter and receiver were thus alternately connected to their aerials. The patent suggests that the commutator rate at each station be different, with one interrupting at 40 times per second and the other at 60 (for example), so that the two cannot drift accidentally into synchronism, with both transmitters and both receivers on the air at the same time.

A more modern break-in system is covered in Patents No. 827,523 and 827,524, issued in 1906. A contact on the end of the telegraph key disables the receiver during transmission. The detector is shorted in one form, and in another the anode of the then-popular electrolytic detector is lifted out of the liquid with which it is normally in contact. This patent shows gaps between the receiver and ground, to short heavy static charges to earth.

An anti-static antenna system is proposed in Patent No. 759,216, application for which was filed May 14, 1902. Two antennas were connected to a single detector in such a way that one would neutralize or "buck" the other. One antenna is tuned to the frequency of the desired signal, the other left untuned. Atmospheric discharges, which would affect both antennas equally, were expected to balance out and produce no response in the detector circuit. The desired signal would produce a much stronger signal in the tuned circuit than in the untuned one, and therefore would be detected.

Patent No. 894,378, applied for in 1903, shows a two-antenna system used for a different purpose. Signals were transmitted simultaneously on two frequencies. Receivers on each frequency were so adjusted that the combined signal from the two antennas would be just strong enough to operate the detector. The system was expected to reduce interference, but there is no reason to believe that a very strong signal on one of the tuned frequencies would not upset the system.

Radiocompass Patents

An early direction finder is described in Patent No. 771,818 (applied for May, 1904). De Forest had already pointed out in his 1902 patent on transmission lines that a two-plate antenna would be directional, since radiation would be at a minimum in a direction edge-on to the plates (Fig. 5-a). The 1904 patent includes a flat plate (A in Fig. 5-b) on pivots C, an electrolytic detector D, battery B, and telephone T. With the plate turned broadside to a signal, reception would be at a maximum. Edgewise on, signal pickup would be at a minimum. A light wire frame of vertical wires could be substituted for the metal plate, which was 6 x 15 feet in size in the inventor's experiments.

A later patent (No. 771,819) shows what looks like a directional dipole, AA' of Fig. 5-c. Being "short as compared with one-quarter wavelength of the received waves" however, it received its strongest signals when end-on to the transmitting station. The same patent describes what is practically a loop antenna (Fig. 5-d). A single wire (inverted-L antenna) pointed away from the distant transmitting station is also claimed to be directional. In a much later patent, No. 1,101,533, the inverted-L directional principle is fully worked out. Several antennas radiate from the station. Switches connect to the equipment the antenna pointing in the direction opposite to that of desired transmission or reception.

The Aerophone

De Forest's first radiotelephony patent (No. 973,644) was applied for in 1906. Called an *aerophone*, it was described as "a wireless telephone in which a resistance device is varied by . . . air vibrations accompanying speech and other sounds." In its simplest form (Fig. 6) it consists of an arc K' between antenna and earth, a generator G, and an oscillating circuit, coil P, condenser C, and arc K'. The microphone K is inductively coupled to the oscillating circuit by transformer T. Its winding P forms part of the oscillating circuit and the microphone is connected across winding S. In another form of the invention, the microphone is connected directly across the arc, through choke coils, and the oscilla-

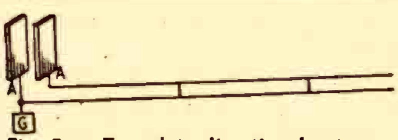


Fig. 5-a—Two-plate directional antenna.

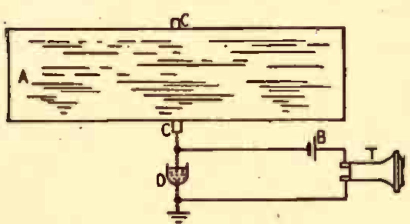


Fig. 5-b—Early direction finder patent.

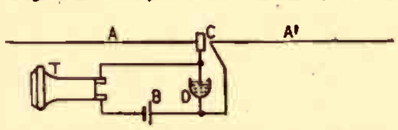


Fig. 5-c—A single-wire direction finder.

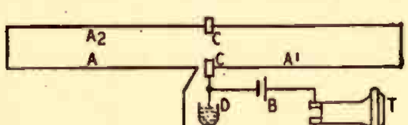


Fig. 5-d—Almost a loop direction finder.

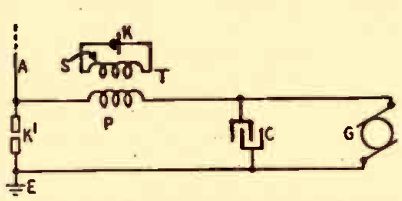


Fig. 6—Earliest de Forest radiophone.

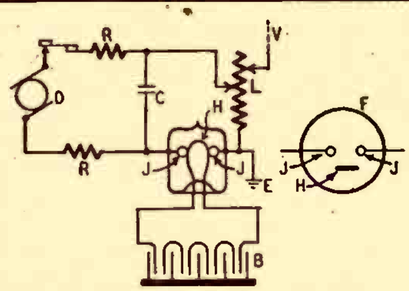


Fig. 7-a—First transmitter with a tube.

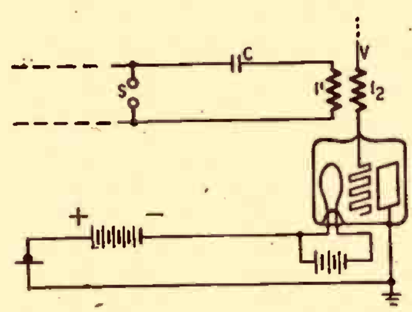


Fig. 7-b—Modulator was a grid audion.

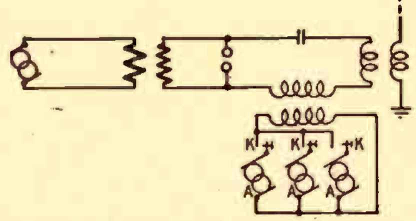


Fig. 8—Transmitter for music-by-radio.

tor and antenna circuits are tuned.

A number of patents (Nos. 850,-917, 913,718, and 995,339) describe improved arc circuits. Patent No. 926,937 shows two arcs connected in parallel to the same antenna. Patent No. 926,936 is an arc transmitter modulated by a low-power spark gap placed either in the d.c. or the oscillating circuit. Other modulated-arc circuits are shown in Patent No. 913,718.

The Grid Audion

The modern vacuum tube first appeared as part of a radiophone circuit in 1907. Application for the fundamental patent on the grid audion was filed on the 29th of January. On the same day an application was made for a patent on a space telegraph or telephone using that tube, as well as earlier types of audions. Patent No. 943,969 (Fig. 7-a) describes a transmitter which uses a two-plate audion as a discharge tube instead of an arc. Apparently the tube acted as a relaxation oscillator. D is a generator, K a key, RR resistors, C a condenser, L an inductor, and V and E the antenna and earth. The audion contains two plates J and a heater H, supplied with current from battery B. Fig. 7-b has an arc S, an oscillation transformer I1 and I2, and a three-element audion in the antenna circuit as modulator. The extremely naive hookup shows how little was then known of the audion.

An *oscillating resistor* was described in Patent No. 979,277. This was a conductor with a negative temperature coefficient, and was installed in place of the arc in an oscillating circuit. The description of this device is somewhat reminiscent of the "talking ceramic" heralded a year or so ago.

Music By Radio

Another 1907 invention, on which the patent (No. 1,025,908) was not granted till 1912, proposed to transmit music by wireless and described an electrical musical instrument. Fig. 8 shows the circuit, a conventional arc transmitter. It is modulated by low-powered alternators A, which supply current at frequencies corresponding to notes in the musical scale. Three of these modulators appear in the figure. Keys K may be manipulated like those of a piano keyboard or an organ manual. De Forest's interest in radio musical devices continued. A circuit with an audion oscillator was invented in 1915 (Patent No. 1,543,900).

Later he invented the *Pianorad*, an instrument with a multiplicity of tubes and speakers.

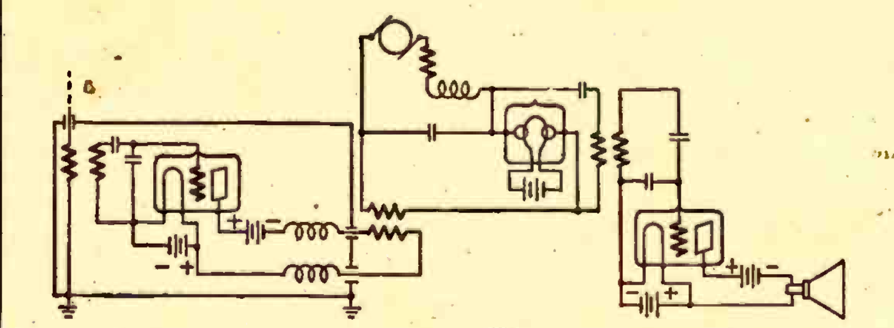


Fig. 9—This 1907 three-tube heterodyne receiver had the first stage shielded.

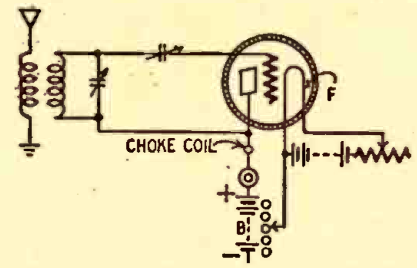


Fig. 12—The first regenerative circuit.

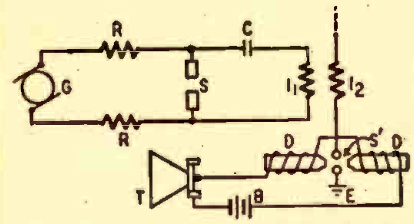


Fig. 10—A magnetic modulator circuit.

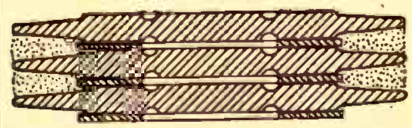


Fig. 11—Section of quenched spark gap.

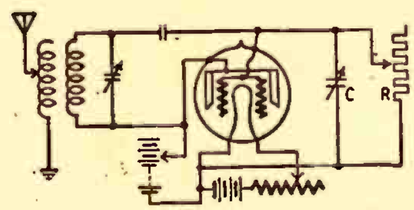


Fig. 13—Audion receiver with grid leak.

A receiver-amplifier invented in 1907 contains many modern features. Covered by Patent No. 995,126 (issued in 1911) it consisted of two grid audions and a discharge tube, which supplied local oscillations (Fig. 9). The first stage, mounted in a metal box, is possibly the first shielded receiver. The output, according to the patent, modulated the continuous oscillations from the two-plate discharge tube (relaxation oscillator). The modulated output was further modulated by a third tube, in the plate circuit of which a telephone was connected.

A magnetic modulation system was another of the inventions of the prolific year 1907. A form in which the magnet coils DD are placed across the gap of a secondary arc in the antenna circuit is shown in Fig. 10. T is the microphone. The other letters indicate the same parts as in other figures. Patent 1,006,635, issued in 1911, covers the invention. Several other patents on systems with magnetic modulators were taken out by de Forest.

Patent No. 1,171,598 (Fig. 11), application for which was made in 1910, covers the quenched gap, with the specially shaped plates and the fiber washers used till spark was outlawed in 1940.

The regenerative receiver is described in Patent No. 1,170,881, for which the application was filed March 12, 1914. As shown in its simplest form in Fig. 12, it could be published today as a simple one-tube ultraudion circuit for the beginner, though it is doubtful if modern tubes would work without the grid leak.

Increased selectivity as well as sensitivity is claimed in the patent. "If the potential in the circuit of battery B and the current in the circuit of filament F are so relatively adjusted that the grid circuit is just ready to be set into oscillation, we find that said circuit is highly responsive to received impulses the group frequency of which is that at which the circuit tends to oscillate, but not sensitive to group frequencies materially differing from the natural period of the grid circuit," says de Forest in describing the action of his "Ultraudion." Use of the detector in an oscillating state was specified, and a drawing of the same circuit as a radio-frequency amplifier appears in the same patent.

The oscillating grid audion is referred to casually in No. 1,170,881, but it was not until September 1914, that an application was made for a patent on an oscillating audion as a transmitter. This patent, No. 1,201,-270, is especially interesting because it covers the *grid leak*. "A high and preferably noninductive resistance" between the grid and filament, says de Forest, increases the energy of the oscillations generated enormously. "For example, from the order of a microwatt to that of tens or hundreds of watts. I have discovered that a still further increase in oscillation energy is obtained if a small capacity is connected in parallel to the resistance." The circuit appears in Fig. 13, complete with resistor R and capacitor C, which actually is a throttle condenser controlling feedback.

Special Tube Types

Metal tubes were patented by de Forest in 1916 and 1917. The earlier patent, No. 1,201,271, proposed a double-walled tube, with a layer of "a suitable liquid, such as mercury" between the walls to overcome the porosity of metals to gases. Patent 1,230,874 shows a single-walled tube, the envelope of which is used as the anode. Metal tubes, the patents stated, could stand rough handling in shipment and use, and would permit greater power outputs than glass tubes.

A multiple-grid tube, with each grid performing its own specialized function, was described in Patent No. 1,311,264, applied for September 4, 1915. It had two inner grids, two outer grids, and two plates. See Fig. 14. Each pair of elements is connected in parallel, and in a modern schematic would be shown as a single element. The inner grid, or grids, is part of the ultraudion oscillating circuit. The outer pair is in the microphone circuit. The present system of suppressor modulation is approximately the same as this one.

Another circuit (Fig. 15) described in the same patent, has a pair of intermeshing coplanar grids reminiscent of those in the Wunderlich tube. The secondary of the microphone transformer is not center-tapped, however, and the supposed action is not quite clear. A number of other interesting circuits are shown in the patent.

Finally, the artistic side of de Forest's nature comes to light in a patent (1,720,544), issued in 1929. It "has for its object the provision of a radio receiving apparatus which is or may be at the same time ornamental," and is nothing less than a radio table lamp (Fig. 16). The standard houses the speaker, and the tuning inductance (actually a loop) is wound round the lower part of the lampshade.

Only a small fraction of de Forest's 200 or more patents can be described in this story of some of his lesser known contributions to the improvement of communication between human beings.

Improved spark transmitters, secrecy devices, special antenna - counterpoise systems, tuning devices strangely like the modern "butterfly" are a few of the other ideas he brought forth. Radio components also received much attention from him. His work on loudspeakers is described elsewhere in this issue.

After 1920, de Forest turned more and more to talking pictures and television, turning out a steady flow of inventions even to the present day. Indeed, he reported to the convention of the Television Broadcasters' Association, October, 1946: "I am carrying on a few experiments in connection with television inventions, which I expect to finish . . . within the next two or three years."

A POEM BY DR. DE FOREST

Although de Forest has written poems at intervals ever since his college days, the poetic side of his many-faceted character has always been overshadowed by his scientific accomplishments. The following poem indicates that he might have succeeded as poet if he had not decided to become an inventor.

California Twilight

I love a pine tree outlined on the night,
Behind it spread a drapery of light,
The moonbeam's weaving witchery's delight,
Mysterious, mysterious!

I love the glimmer of a mountain stream
When twilight's glow has faded to a dream
In pools where stars descending seem
Pendulous, pendulous!

I love the shadows of the spectral hill
Across the canyon when the night is chill,
And silence seals the river singing still,
Melodious, melodious!

—LEE DE FOREST

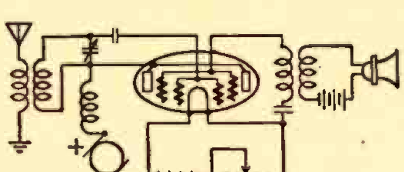


Fig. 14—Multiple-grid tube transmitter.

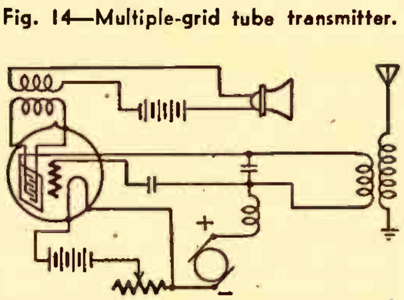
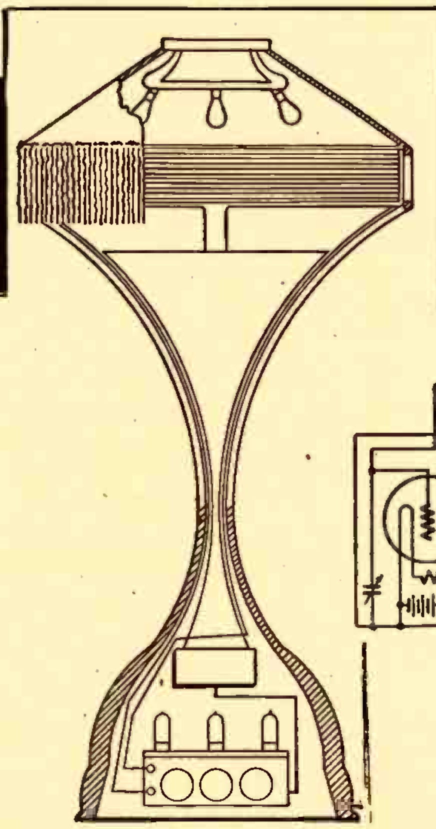


Fig. 15—Variation of the above circuit.



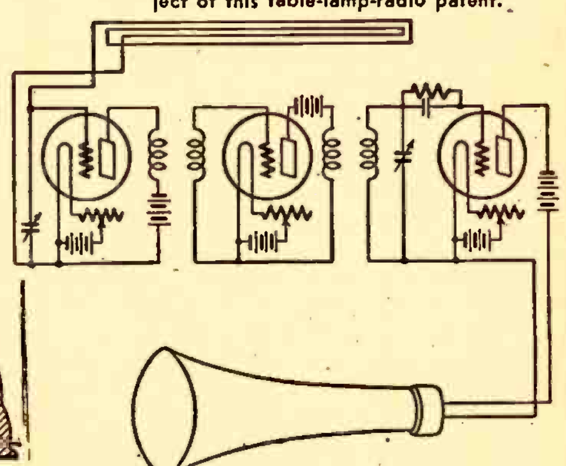


Fig. 16—An ornamental receiver is the object of this table-lamp-radio patent.

E. I. Co. Sold First Audions

By Hugo Gernsback

WAY back in 1907, when Dr. Lee de Forest was experimenting with his first three-element audion, the Electro Importing Company, which had been started by the writer in 1904, was going full blast, supplying wireless apparatus and instruments to early experimenters and amateurs.

The first catalogs of the E.I.Co.—in their wireless sections—dealt principally with coherers. It was not until the year 1906 that the writer brought out the *Auto-Coherer*, which was illustrated on page 25 of the Electro Importing Company's Catalog No. 3.

Previous to that we had been selling the coherer and decoherer instrument, but as it could not receive signals over distances of more than a few miles, the Auto-Coherer was brought out. This Auto-Coherer was sold for many years by the E.I.Co. It was used in connection with a telephone receiver, rheostat and battery and brought in signals over fair distances.

It was not until 1908 in its Catalog No. 5 that the E.I.Co. featured its first crystal detector, in which carborundum, molybdenum, or silicon could be used.

In the same catalog was also featured an electrolytic detector which was invented by the writer. The original electrolytic type of detector had been invented by Dr. Fessenden, but it required a battery for its operation. I eliminated the battery by making a primary battery out of the detector itself. I used a carbon cup which held the acid; then the fine Wollaston wire became the other element of the battery. Thus was combined, for the first time, a battery and a detector all in a simple instrument.

Thus things stood until the year 1911 when we brought out E.I.Co. Catalog No. 10, in which was featured for the first time de Forest's audion. Wireless had now arrived in earnest!

The E.I.Co. when it announced the audion on page 93b of Catalog No. 10, made history in that it was the first time that Lee de Forest's audion was sold commercially to the public. The page showing the historic advertisement of the audion is reproduced here.

For several years the audion was advertised in E.I.Co. catalogs and in MODERN ELECTRICS, the writer's former magazine—the first radio magazine in print up to that time.

What I did not know until recent years, however, was the fact that the Electro Importing Company not only sold the first audion to the public, that is, to radio experimenters and amateurs, but that is also sold by far the largest quantity of audions between the years 1911-1913, of any company in the world. The following figures, which were taken from records of the McCandless Incandescent Lamp Company, makers of the first audions, are most interesting. They were used in one of Dr. de Forest's patent suits.

It appears that the following firms were users of audions. First, of course, de Forest himself and his various companies. It should be noted that the de Forest concerns did not sell audions in the years between 1909 and the end of 1913, but used them in various wireless telegraph and telephone sets which they sold *complete.* As far as is known none of these sets were sold direct to the public, but to services such as the Navy, etc.

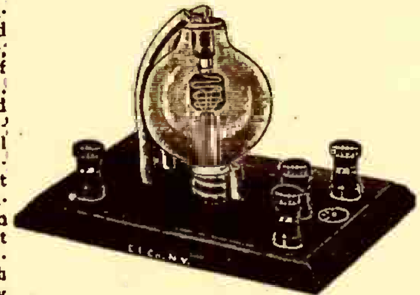
The Electro Importing Company marketed its first audion in June, 1911. During that year the company

(Continued on page 49)

93b

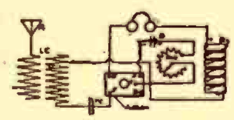
THE "ELECTRO" AUDION.

After long deliberation, we herewith present the best audion manufactured to-day in the United States. Of all the detectors in use, none present the accumulation of advantages offered by the Audion, the "Electro" model being designed from the result of long and extended experiments. While the crystal types of detector present many advantages, they have the one great defect of not holding their adjustment, especially on receiving from a nearby station. The Audion, not only ranks as the highest in sensitiveness, but possesses that much sought for characteristic, stability of adjustment. Loud signals do not affect the adjustment, and, on the contrary, seem to improve the sensitiveness. When receiving from loud or nearby stations, the light will be noticed to flicker in the bulb, and the signals can thus be read without the use of a telephone receiver, this feature being found in no other detector. Signals received by the Audion are extremely loud, and most stations in the vicinity of the receiving station may be heard with the phones three feet or more from the operator's ears.



8200

The "Electro" Audion, consists of a vacuum bulb containing two filaments of tantalum, connected in series with a lead taken off at the connecting point of both filaments. One filament is used at a time, and at the exhausting of one filament, the other may be resorted to. This gives double the life which is obtainable from other audions. The filaments are used on 4 volts, which may be obtained from storage battery or dry cells. The bulb also contains a wire which is bent in a zig-zag form, and called the "grid." A small sheet of nickel foil is also contained in the bulb. It is behind the grid and the metal foil. Under normal conditions, the current from a 30-35 volt battery connected with a telephone receiver has great difficulty in passing through the heated vacuum space. However, on reception of the wave trains, the current from the battery passes through the vacuum and produces an audible sound in the receiver. The audion is the most suited detector for wireless telephony, owing to its faithful reproduction of every wave. The 30-35 volts required for the telephone receiver circuit, may be obtained from 6 to 7 flash light batteries. Inasmuch as the current used is practically zero, a set of these cells will last for a long time. The apparatus is connected as shown in the diagram. In this instance a loose-coupler is shown, giving the set the maximum degree of selectivity. The rotary rheostat is also used, our No. 5000, which is very suitable for this purpose in regulating the filament current. The flash lamp dry cells are also shown connected in series with the telephone receiver. Here it might be stated that the audion will give excellent results on low voltage telephone receivers, though, of course, the better the receivers the further the range.



Full instructions given with each instrument. Size of base, 5¼ in. x 3½ in. Height, 3½ in. Weight, ¼ lb.

No. 8200. The "Electro" Audion as described and illustrated...... $4.00
By mail extra, shipped in heavy wooden box 0.25

The first Audion advertisement appeared in Catalog 10 of the E.I.Co., New York, 1911.

DE FOREST  THE INVENTOR

By H. Winfield Secor

SOME of the most interesting patents granted to Dr. Lee de Forest were not in the field of radio. These less well-known inventions cover such diverse fields, as diathermy, talking pictures, photo-electric devices, range finders, television apparatus and airplane instruments.

Cautery Device

One of the early de Forest medical patents disclosed an idea for a high frequency cautery device. Patent No. 874,178 was issued on it Dec. 17, 1907. An oscillating or singing arc R (Fig. 1) was the exciter for the cautery electrode. A tuned circuit comprising a condenser C and an inductance I_1 is shunted across the arc A; this inductance may be the primary coil of the air-core transformer used to transfer the high-frequency current to the cautery electrode E. E^1 is the ground electrode. Frequencies of 500 to 1,000 kc are suggested.

Dr. de Forest has experimented considerably in the shortwave diathermy field. His patent No. 2,126,541 provides a unique design for such apparatus. The output or treatment electrodes are excited by vacuum-tube oscillators 0-0 in a circuit tunable from 3 to 13 meters. A coiled Lecher wire system L is used; this gives the advantages of the distributed capacity and inductance of the Lecher system and at the same time greatly reduces the dimensions of the apparatus. See Fig. 2.

Tube-less Amplifier

A tube-less amplifier of the dynamic type is the unusual device covered in patent No. 1,134,594, dated Apr. 6, 1915. A series of magnetic windings A, B, C, on iron cores are placed in close proximity to a revolving metal disc, similar to the arrangement in a homopolar dynamo. (See Fig. 3.) The signals to be amplified are passed through the several coil windings in progressive order, and as the inventor states, "there is thus provided a means of dynamically amplifying minute current impulses, imparting thereto new energy from a local source . . . without moving contacts, microphonic or otherwise . . . and without ohmic resistance or resistance-altering devices." A unique invention, to say the least, and worth study by all electrical and radio students.

Telegraphone

Magnetic wire recorders engaged the attention of de Forest at an early date. Two patents involving the use of such devices are No. 1,375,447, Apr. 19, 1921 and No. 1,177,848, Apr. 4, 1916. The first patent describes means for reproducing sounds from magnetic sound records (steel wire recorders). The second covers the procedure for magnetically recording the amplified pulsating current thus produced. The originating wire recorder A may have its steel wire magnetized by sound waves (electric voice currents) in the usual manner. This device permits one to make a *duplicate copy* B of a telegraphone record. See Fig. 4.

Subterranean Signalling System

Transmitting and receiving high frequency signals through the earth is proposed in patent No. 1,424,805 (Aug. 8, 1922). The transmitter and receiver are connected to earth through buried metal plates separated quite a distance. The earthed circuit is preferably tuned to the generator frequency by suitable tuning means. Advantage claimed is the freedom from atmospheric disturbances.

Pneumatic Telephone

The transmission and reception of speech or other sounds, such as tele-

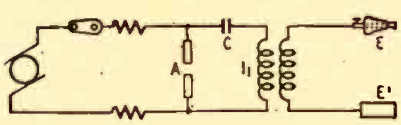


Fig. 1—A high-frequency surgery patent.

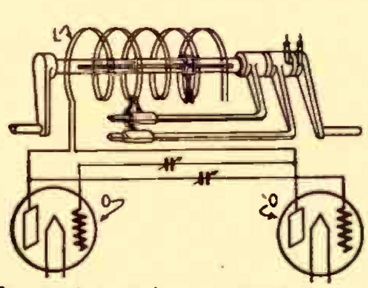


Fig. 2—A special circuit for diathermy.

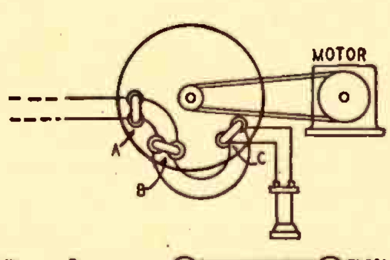


Fig. 3—Dynamic amplifier without tubes.

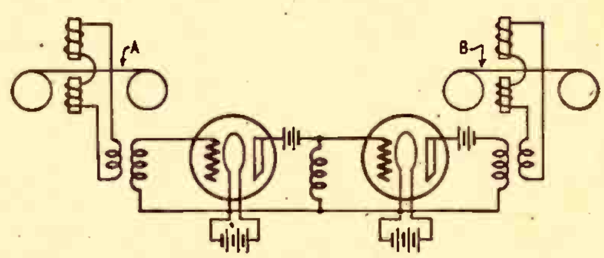


Fig. 4—Means for reproducing magnetic-wire sound records.

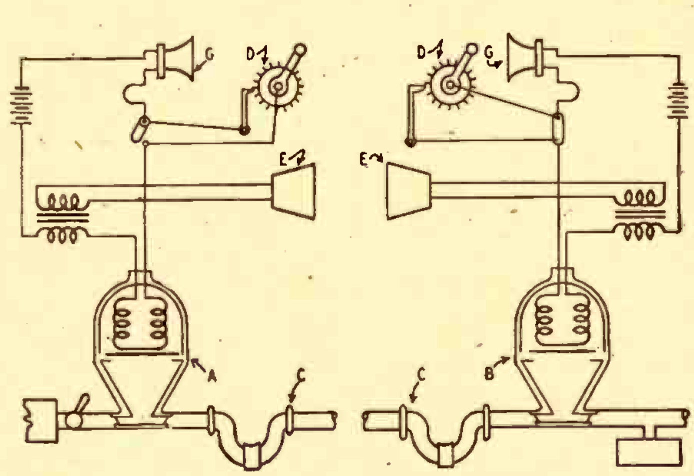


Fig. 5—A pneumatic telephone for communication on trains.

graph signals, over the air-brake pipe line extending along a train of standard railroad cars, is described in patent No. 1,515,152, Nov. 11, 1924. See Fig. 5. Magnetically controlled air pulsators (A and B) are used to impress the sound vibrations upon the air column in the pipe line C (the air brake and signal lines).

Stations are called by means of interrupters D (noise producers). When the engineer or conductor hears a buzz-saw note in the receiver, he knows that he should listen for a message.

The sound waves induced in the air line are picked up by the magnetic pulsators, the vibrating air column causing a diaphragm to vibrate and in turn induce electric currents of corresponding frequency in coils placed behind the diaphragm. These voice currents may be amplified, and are connected to a standard type telephone receiver E or loudspeaker. Microphones are marked G.

Thermionic Phono Pickup

Electric pickups for phonographs have become very popular in recent years. De Forest received an interesting patent—No. 1,554,561—date Sept. 22, 1925—for a phono pickup operating on the thermionic principle. The sound vibrations picked up by the needle A in contact with the phonograph record are transmitted to a grid member B sealed into an evacuated glass chamber, as shown in Fig. 6. A heated filament within the tube supplies an ionized field; vibrations of the grid cause corresponding modulation of the current in the circuit connected to the electrodes of the tube. The output of the thermionic pickup may be connected to a vacuum tube amplifier and any desired amplification of the sound readily obtained.

The pickup is strongly reminiscent of the *Vibrotron*, a 1946 tube based on much the same principles.

Diffraction Microphone

A novel diffraction microphone invented by de Forest Aug. 27, 1929, is described in patent No. 1,726,289. In this device a beam of light is flashed onto a photocell. A polished mirror A is interposed in the path of the beam of light; this mirror is electrically heated. (See Fig. 7). It was found that sound waves striking the heated layers of air in proximity to the mirror caused changes in their diffracting powers and consequent variations or diffraction in the beam of light. In turn these variations in the beam of light are recorded by the photocell B, connected in a telephone or modulator circuit; the pulsations in the voice are thus reproduced in the circuit controlled by the photocell.

Gaseous Microphone

A noise-free microphone of the gaseous type forms the subject of patent No. 1,834,051—dated Dec. 1, 1931. The microphone is built into a glass and metal cylinder A, fitted with a flexible gas-tight diaphragm D at one end. See Fig. 8. An electrically heated cathode C is mounted a short distance behind the flexible metal diaphragm. Voice (air) waves striking the diaphragm cause variations in the ionized field between it and the heated cathode, causing fluctuations in the current in the main telephone circuit connected to the microphone. The chamber may be exhausted to a high degree and a slight amount of gas admitted.

Loudspeakers

De Forest was much interested in loudspeakers.

A diaphragmless loudspeaker is described in patent No. 1,641,664—Sept. 6, 1927. As Fig. 9 shows, two spirally wound strips, insulated from each other, are connected to the output of an amplifier or other voice current supply. The cathode strip A is heated to provide an ionized field between the two spiral conductors. B is the anode; C is the heating current source. When this field is modulated by the voice current, the surrounding air has sound waves set up in it, in the manner of the speaking arc. The cathode spiral strip may be made of fine woven wire, loaded with certain oxides of the rare earths to intensify the electronic emission.

Other patents on loudspeakers include No. 1,560,502—a means of vibrating a curved loudspeaker member. The actuating device or motor for driving a loudspeaker is the subject of patent No. 1,718,337. A novel cone speaker is illustrated and described in patent No. 1,554,794. Another diaphragm-less type speaker is described in patent No. 1,486,866. A sealed inflated elastic body has wires wound around its exterior surface, which causes it to contract and expand in accordance with the fluctuations of the voice current impressed on the microphone M. See Fig. 10.

A table-lamp speaker appears in patent No. 1,452,827—Apr. 24, 1923, and a cylinder type speaker in patent No. 1,736,035—Nov. 19, 1929.

A novel speaker mechanism designed for controlling the escape of compressed air in accordance with the undulations of the voice current applied to it, is described in patent No. 1,766,612—June 24, 1930. This speaker is intended for use where powerful sound waves are to be reproduced. The voice coil moves longitudinally in the field of a strong electromagnet, and causes slots in a valve to open and close in exact proportion to the fluctuating strength of the voice current. See Fig. 11.

Compressed air is admitted through pipe A which passes clear through the center core of the magnet. The magnet is excited by direct current. A brass dome B is threaded onto the upper end of the magnet core. This dome has slits C cut into it, through which compressed air from the tube A can pass, whenever the sliding sleeve D is moved up and down by the voice coil and uncovers the slits.

A corrugated diaphragm E supports the moving voice coil G and the valve sleeve. The compressed air liberated through the slits is in direct proportion

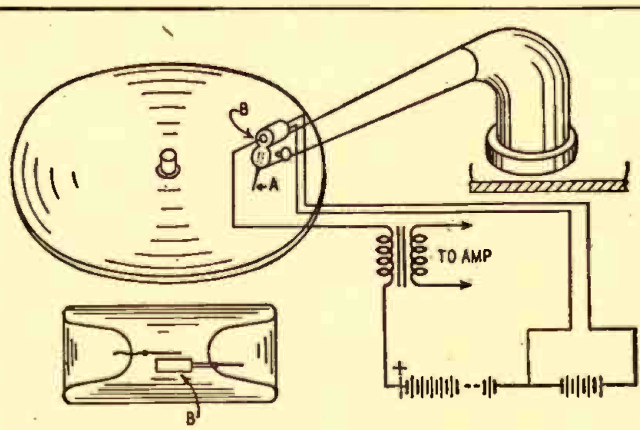


Fig. 6—This phonograph pickup works on the thermionic principle.

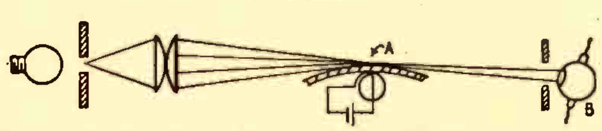


Fig. 7—A microphone which employs a vibrating mirror and photocell.

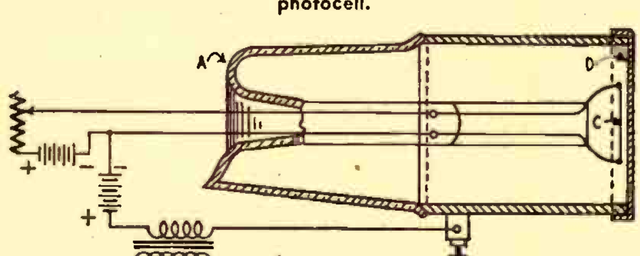


Fig. 8—A gaseous-tube microphone with vibrating anode-diaphragm.

to the strength of the varying voice current, thus creating powerful sound waves in the horn attached to the air-valve chamber.

A combination cone and horn speaker is described by de Forest in patent No. 1,785,377—Dec. 16, 1930. See Fig. 12. This combination has been found to reproduce the broad band of voice frequencies more satisfactorily than either speaker alone. Another similar type speaker of large proportions, for use where a great volume of sound is desired is covered by patent No. 1,853,850.

Thermophone

A loudspeaker of the *diaphragm-less* type, operating on the hot-wire or thermophone principle, was invented by de Forest Feb. 17, 1925. See his patent No. 1,526,778 and Fig. 13.

A fine wire W is concentrated in an insulating disc D (or at the focus of a parabolic reflector in one form), fitted with a perforated cover through which the sound emerges.

The heating effect of undulating voice currents causes the fine wire to expand and contract. These rapid thermal changes are communicated to the adjacent air envelope and set up sound waves therein.

One of the advantages of the thermal type speaker is the faithful reproduction of sound. The principle involved is worthy of further study by our engineers intent upon high-fidelity music and speech reproduction.

An unusual scientific principle is involved in a loudspeaker (or microphone) covered by patent No. 1,738,988. It utilizes variations in the capillary boundary between two liquids of differing densities. See Fig. 14.

With mercury and dilute acid, for example, placed in a capillary tube, a meniscus or semi-globular surface forms between them. If a varying (voice) current is applied to such a tube through suitable electrodes making contact with the acid A and the mercury, B, the current will cause the contact surface or meniscus, C, between the two liquids to rise and fall within the tube. This action in turn will create sound waves in the acoustic horn chamber shown in the picture. This is the *loud-speaker* action.

When used as a *microphone* the reverse action occurs . . . the sound waves strike the liquids in the capillary tube and cause the meniscus to rise and fall. If an electric current is connected to the tube terminals, variations corresponding to the voice fluctuations in this current will be created (in the external circuit). A loudspeaker connected in this circuit will reproduce the sounds originating at the capillary microphone.

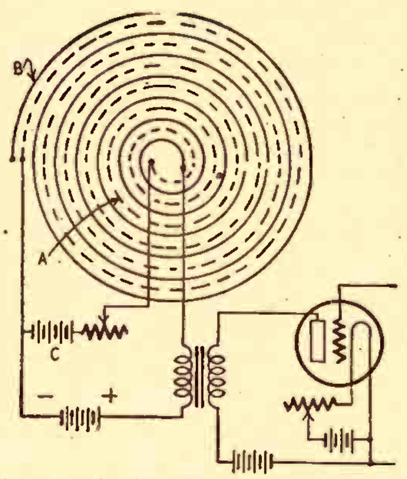


Fig. 9—A loudspeaker which works on air.

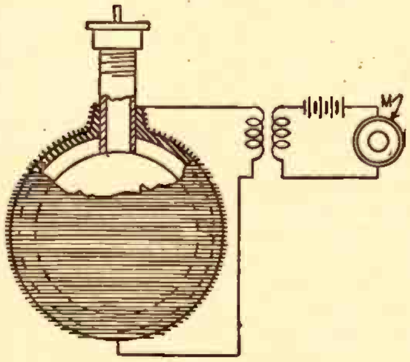


Fig. 10—Another interesting loudspeaker.

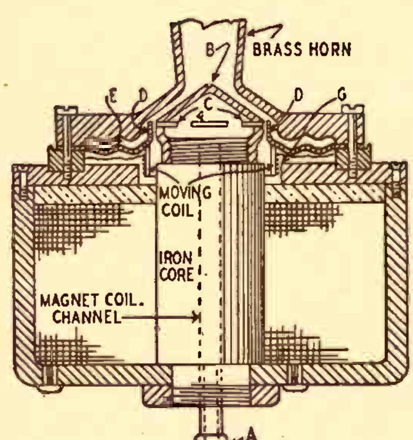


Fig. 11—Air-blast "very loud" speaker.

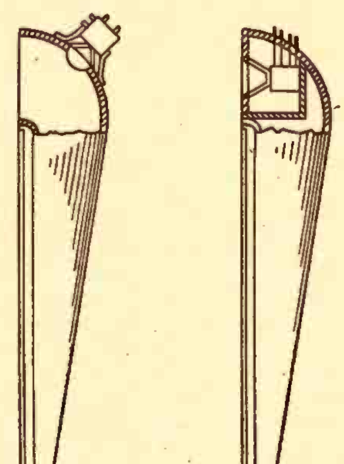


Fig. 12—Combined horn and cone speaker.

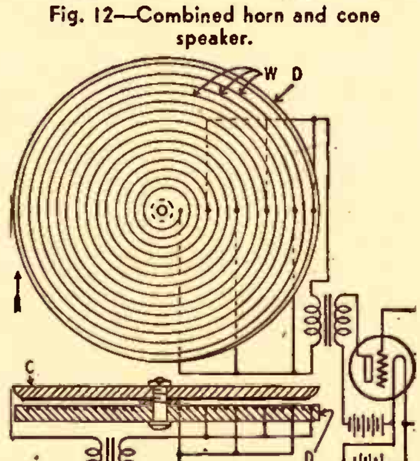


Fig. 13—Another heat-operated speaker.

Talking Pictures

Dr. de Forest performed a great deal of research on devices to improve the early talking pictures. An early patent, No. 1,482,119, Jan. 29, 1924—describes a method for recording the picture and the voice record on the same film simultaneously. An early arrangement used an arc for recording the voice patterns on the film. Some more stable form of glow discharge was desirable, and one of de Forest's designs for a glow tube that could be modulated by the voice current, is covered in patents No. 1,806,746, May 26, 1931, and No. 1,873,558, Aug. 23, 1932. See Figs. 15 and 16. The glow or corona A was concentrated at one end of the tube and was of high intensity. The voice current, when super-imposed on the electrodes B and C of the glow tube, caused the intensity to vary.

Binaural recording and reproduction of sound is interestingly described in patent No. 1,769,907 of July 1, 1930. This has to do with speakers placed in different parts of the theater, each speaker reproducing certain frequencies and thus giving a *third-dimension* sound effect.

Photo-Electric Cell

An improved photocell was devised and patented by de Forest, July 30, 1929 (Patent No. 1,722,280). See Fig. 17. The light-sensitive cell A is made in a flattened *lenticular* shape so that the electrodes within the cell will be located only a short distance from the film B on which the sound track is impressed. A steady source of light projects a beam of light through the film sound track upon the photo-cell.

Television

One of the earliest television patents of de Forest, No. 2,003,680 was issued June 4, 1935. It describes a television receiving and projecting method for scanning a strip of specially prepared film and electrically etching pictures thereon. Patent 2,026,872, issued in 1936, describes a means of producing a large size television image. The received image is recorded on specially treated film and may be later projected onto a screen by the usual projector. Sound is reproduced by a sound track recorded on the picture film at the same

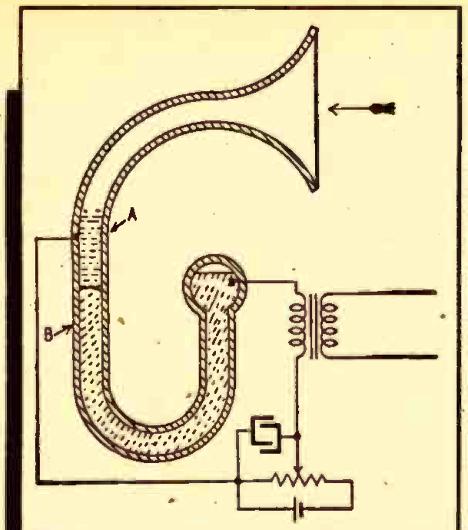


Fig. 14—A unique loudspeaker principle.

time the picture signals are recorded. An ingenious metho' for recording or etching the picture images on the coated film by an electrostatic discharge is described. The discharge is modulated by the received television signals. A following patent covers further developments of this idea and includes means for synchronizing the received images with the accompanying sound signals.

An idea for stereoscopic television is covered by patent 2,163,749. Radial scanning is one of the features here proposed. A cathode beam radial scanning system appears in patent 2,241,809 issued May 13, 1941. The cathode beam is deflected back and forth by a rotating switching device; thus the beam traverses a non-repeating pattern on the screen.

Television Sign

A television sign is described in patent No. 2,049,763 dated August 4, 1936. In the future we shall undoubtedly see many signs of this type along our highways. It is operated by remote control from a television station. A salient feature of this television sign is that practically any picture can be reproduced on its face, either in silhouette or halftone effect. The glow lamps on the surface of the sign are controlled by a switch directed by television signals, which may be picked up by a television receiver located near the sign. These signs may be operated out in the open country and a number of signs can be controlled at the same time from one transmitter.

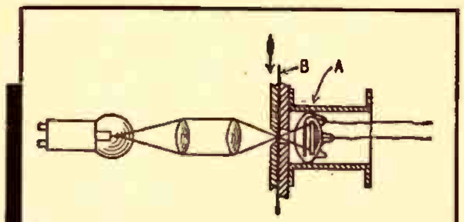


Fig. 17—A photocell for sound recording.

The patent describes the preferred form of the high-voltage glow tubes and the switching mechanism. In one

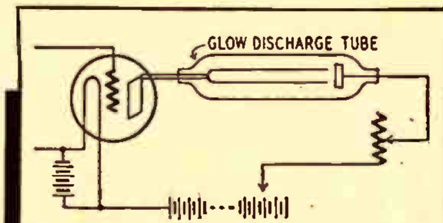


Fig. 15—Sound movie glow-discharge lamp.

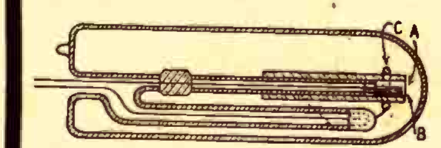


Fig. 16—Another talking-picture lamp.

suggested form the sign might contain a hundred rows of glow tubes, with a hundred tubes in each row. Ten thousand glow tubes would be used in this case and thus a very good reproduction of the image realized. High voltage is fed to each glow tube as the commutator switch makes the proper connection, in accordance with the television signal directing it.

Many of the above inventions were not followed up, for one reason or another. They offer challenging opportunities for the engineer or experimenter today. Certain speakers, for instance, were not practical when 90 volts of B battery was a standard power supply but might be quite usable now that 450 or even 900 volts can be obtained if desired. These patents are worth study.

E. I. CO. SOLD FIRST AUDIONS

(Continued from page 45)

sold 93 audions. In 1912 it sold 155 audions and in 1913 it sold 211, a total of 459. It should be noted that this compares rather well with all the de Forest companies combined, which from 1909 until the end of 1913 bought a total of 1,300 audions from McCandless.

The next runner-up in point of early purchase of audions was the Manhattan Electric Supply Company, which started with a single audion, bought from McCandless in September, 1911. But the Manhattan Electric Supply Company bought only 10 audions in 1911-1912.

The next fairly large user, second in point of sales to the public, was the J. H. Bunnell Company of New York. This company, however, did not start selling audions until January, 1912. During 1912-1913 they sold a total of 384 audions against the E.I.Co.'s 459.

The third concern to sell audions to the public was Wallace & Company. They did not start, however, until February, 1912; during 1912-1913 they sold a total of 280 audions.

A few other wireless supply companies also sold audions to the public, but their sales did not come anywhere near the totals cited above.

Of passing interest also is the fact that Western Electric Company—who did not sell the tubes to the public, but used them for experimental purposes —during the same years bought 45 audions from the McCandless Company. The Marconi Wireless Telegraph Company of America, which during the year 1909-1913 bought a total of 74 audions, was in the same class. None of these were sold to the public.

For the record, it might also be noted that the E.I.Co. did not make much profit on their audion sales. They paid between $1.50 and $2.00 per audion tube to the McCandless Company and sold it to the experimenters and amateurs for $4.00. This price was, of course, not just for the audion itself. The E.I.Co. mounted it on a substantial wooden base with five binding posts and socket; then it had to be wired, too. At such a price, little profit was realized.

The reader may be interested in the following taken from a forthcoming book by Mr. Gerald F. J. Tyne, *McCandless and the Audion:*

"The Electro Importing Company was the child of Hugo Gernsback, now publisher of RADIO-CRAFT, founder of MODERN ELECTRICS, ELECTRICAL EXPERIMENTER, RADIO NEWS, SHORT-WAVE CRAFT, and similar publications, and entrepreneur extraordinary. Gernsback sold great quantities of wireless apparatus in the period 1908-1915, mostly on a mail order basis. Many amateurs of that day (including the writer) considered the E.I.Co. catalog as a second Bible. McCandless-made [de Forest] tubes were sold by the E.I.Co. under the name of the 'Electro Audion.'

"The 'Electro Audion' first appeared in the E.I.Co. Catalog No. 10 for the year 1911 on page 93b and was first advertised by them in MODERN ELECTRICS for July, 1911, on page 272. The last appearance of the 'Electro Audion' in the E.I.Co. Catalog was on page 11 of the 1913 issue. . . . In this connection the following statement made in this advertisement is worthy of note:

" 'When receiving from loud or nearby stations, the light will be noticed to flicker in the bulb, and the signals can be read without the use of a telephone receiver, this feature being found in no other detector.'

"The E.I.Co. went out of business about 1920 and Gernsback thereafter devoted his talents almost exclusively to publishing."

DE FOREST PATENTS

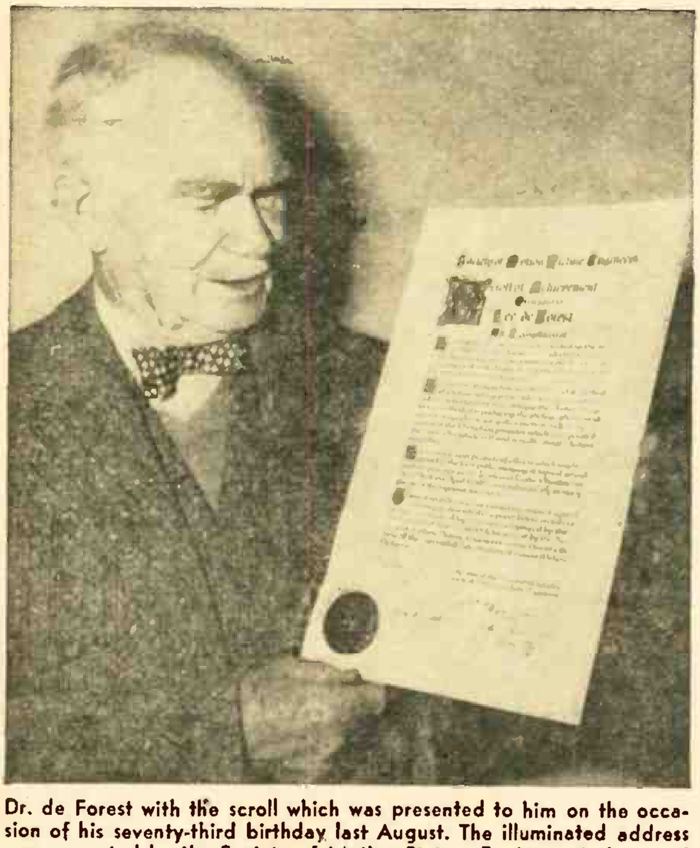
1902 — 1946

The most important de Forest patents have been described in two articles elsewhere in this issue. Dozens of other inventions would have been well worthy of mention had space been available. The following list, with dates of patents and a brief description of the main features of each invention (not necessarily the patent title) may be interesting to many readers.

716,000, Dec. 16, 1902, Apparatus for Space Communications
716,203, Dec. 16, 1902, Wireless Telegraphy
716,334, Dec. 16, 1902, Method of Communicating Through Space
720,568, Feb. 17, 1903, Space Telegraphy
730,246, June 9, 1903, Space Telegraphy
730,247, June 9, 1903, Wireless Telegraphy
730,819, June 9, 1903, Wireless Signalling
748,597, Jan. 5, 1904, Wireless Signalling Device
749,131, Jan. 5, 1904, Wireless Signalling Apparatus
749,178, Jan. 12, 1904, Wireless Signalling Apparatus
749,371, Jan. 12, 1904, Wireless Telegraph Receiver
749,372, Jan. 12, 1904, Art of Wireless Telegraphy
749,434, Jan. 12, 1904, Wireless Signalling Apparatus
749,435, Jan. 12, 1904, Wireless Telegraphy Generating Set
749,436, Jan. 12, 1904, Wireless Telegraph Range Finder
750,180, Jan. 19, 1904, Spark Production Control Method
750,181, Jan. 19, 1904, Device for Cleaning Ice from Antenna
758,517, Apr. 26, 1904, Art of Wireless Telegraphy
759,216, May 3, 1904, Wireless Signalling Apparatus
770,228, Sept. 13, 1904, Receiver for Space Signalling
770,229, Sept. 13, 1904, Wireless Signalling Apparatus
771,818, Oct. 11, 1904, Wireless Signalling Apparatus
771,819, Oct. 11, 1904, Wireless Signalling Apparatus
771,820, Oct. 11, 1904, Protecting High Frequency Apparatus
772,878, Oct. 18, 1904, Magnetic Detector
772,879, Oct. 18, 1904, Art of Duplex Wireless Telegraphy
806,966, Dec. 12, 1905, Wireless Telegraph System
822,936, June 12, 1906, Wireless Telegraph System
823,902, June 12, 1906, Static Valve for Wireless Systems
824,003, June 19, 1906, Wireless Telegraph System
824,637, June 26, 1906, Oscillation Responsive Device
824,638, June 26, 1906, Oscillation Responsive Device
827,523, July 31, 1906, Wireless Telegraph System
827,534, July 31, 1906, Wireless Telegraph System
833,034, Oct. 9, 1906, Aerophone
836,015, Nov. 13, 1906, Aerophone
836,070, Nov. 13, 1906, Oscillation Responsive Device
836,071, Nov. 13, 1906, Oscillation Responsive Device
836,072, Nov. 13, 1906, Aerophone
837,901, Dec. 4, 1906, Wireless Telegraphy
841,386 Jan. 15, 1907, Wireless Telegraphy
841,387, Jan. 15, 1907, Device for Amplifying Feeble Currents
850,917, Apr. 23, 1907, Space Telegraphy
852,381, Apr. 30, 1907, Wireless Telegraph Receiving System
867,876, Oct. 8, 1907, Oscillation Responsive Device
867,877, Oct. 8, 1907, Art of Detecting Oscillations
867,878, Oct. 8, 1907, Oscillation Detector
874,178, Dec. 17, 1907, Cautery
876,165, Jan. 7, 1908, Wireless Telegraph Sending System
877,069, Jan. 21, 1908, Magnetic Detector
879,532, Feb. 18, 1908, Space Telegraphy
894,317, July 28, 1908, Electrolytic Detector Electrode
894,318, July 28, 1908, Aerophone
894,378, July 28, 1908, Wireless Signalling Apparatus
913,718, Mar. 2, 1909, Space Telegraphy
926,933, July 6, 1909, Wireless Telegraphy
926,934, July 6, 1909, Wireless Telegraph Tuning Device
926,935, July 6, 1909, Wireless Telegraph Transmitter
926,936, July 6, 1909, Space Telegraphy
926,937, July 6, 1909, Space Telephony
943,969, Dec. 21, 1909, Space Telegraphy
966,539, Aug. 9, 1910, Transmitting Apparatus
973,644, Oct. 25, 1910, Aerophone
979,275, Dec. 20, 1910, Oscillation Responsive Device
979,276, Dec. 20, 1910, Space Telegraphy
979,277, Dec. 20, 1910, High Frequency Oscillator
995,126, June 13, 1911, Amplifier for Feeble Electric Currents
995,339, June 13, 1911, Space Telegraphy
1,006,635, Oct. 24, 1911, Space Telephony
1,006,636, Oct. 24, 1911, Space Telephony
1,025,908, May 7, 1912, Wireless Music Transmitter
1,042,205, Oct. 22, 1912, Duplex Wireless Transmission System
1,101,533, June 30, 1914, Wireless Telegraphy
1,123,118, Dec. 29, 1914, Signalling System
1,123,119, Dec. 29, 1914, Wireless Communication Secrecy System
1,123,120, Dec. 29, 1914, Space Communications Arc Mechanism
1,125,496, Jan. 19, 1915, Wireless Telephone Transmitter
1,134,593, Apr. 6, 1915, Electromagnetic Radiation Receiver
1,134,594, Apr. 6, 1915, Increasing Strength of Electric Currents
1,170,881, Feb. 8, 1916, Wireless Receiving System
1,170,882, Feb. 8, 1916, Telephone System Automatic Switch
1,171,598, Feb. 15, 1916, Radiotone Wireless Telegraph Spark Gap
1,177,848, Apr. 4, 1916, Method of Recording Fluctuating Currents
1,183,802, May 16, 1916, Range Teller
1,183,803, May 16, 1916, Wireless Telephone System
1,190,869, July 11, 1916, Quench Spark Discharger
1,201,270, Oct. 17, 1916, Oscillating Current Generator
1,201,271, Oct. 17, 1916, Oscillating Audion
1,201,272, Oct. 17, 1916, Telegraph and Telephone Receiving System
1,201,273, Oct. 17, 1916, Oscillation Generator
1,214,283, Jan. 30, 1917, Wireless Telegraphy
1,221,033, Apr. 3, 1917, Wireless Telegraph Signalling System
1,221,034, Apr. 3, 1917, Oscillating Current Generator
1,221,035, Apr. 3, 1917, Wire or Radio Communications Apparatus
1,230,874, June 26, 1917, Metallic Audion
1,299,356, Apr. 1, 1919, Radio Communication Apparatus
1,309,753, July 15, 1919, Vibrations Transducer
1,311,264, July 29, 1919, Oscillation Generator
1,314,250, Aug. 26, 1919, Current Pulse Reproducer and Amplifier
1,314,251, Aug. 26, 1919, Radiotelephony
1,314,252, Aug. 26, 1919, Oscillation Generator
1,314,253, Aug. 26, 1919, Wire or Radio Communication Apparatus
1,329,758, Feb. 3, 1920, Oscillating Current Generator
1,348,157, Aug. 3, 1920, Amplifier for Pulsating Electric Currents
1,348,213, Aug. 3, 1920, Radiotelephone System
14,959, Reissued Oct. 19, 1920, Wireless Telephone System
1,365,157, Jan. 11, 1921, Apparatus for Telegraphy or Telephony
1,365,237, Jan. 11, 1921, Endless Film Arrangement
1,375,447, Apr. 19, 1921, Means for Amplifying Currents
1,377,405, May 10, 1921, Audion Circuit
1,397,575, Nov. 22, 1921, Selective Audion Amplifier
1,417,662, May 30, 1922, Radio Signalling System
1,424,805, Aug. 8, 1922, Subterranean Signalling System
1,437,498, Dec. 5, 1922, Oscillion

1,442,426, Jan. 16, 1923, Sound Controlled Light Variations
1,442,682, Jan. 16, 1923, Endless Sound Record and Mechanism
15,540, Reissued Feb. 13, 1923, Changing Motion to Electricity
1,446,246, Feb. 20, 1923, Recording and Reproducing Sound
1,446,247, Feb. 20, 1923, Light Controlling Means
1,452,827, Apr. 24, 1923, Telephone Device
1,466,701, Sept. 4, 1923, Light Variation Current Control
1,478,029, Dec. 18, 1923, Radio Receiving System
1,482,119, Jan. 29, 1924, Recording and Reproducing Sound
1,486,866, Mar. 18, 1924, Sound Producer
1,489,314, Apr. 8, 1924, Recording Sound
1,507,016, Sept. 2, 1924, Radio Signalling System
1,507,017, Sept. 2, 1924, Wireless Telegraph and Telephone
1,515,152, Nov. 11, 1924, Communication System for Trains
1,526,778, Feb. 17, 1925, Thermophone
1,543,990, June 30, 1925, Producing Musical Notes Electrically
1,552,914, Sept. 8, 1925, Telephone Device
1,554,561, Sept. 22, 1925, Sound Reproducing Mechanism
1,554,794, Sept. 22, 1925, Loud Speaking Device
1,554,795, Sept. 22, 1925, Radio Signalling System
1,560,502, Nov. 3, 1925, Sound Reproducing Device
1,561,596, Nov. 17, 1925, Indicating Device for Fluid Tanks
Des. 69,443, Feb. 16, 1926, Loud Speaker
1,629,152, May 17, 1927, Slot Cleaner for Motion Picture Machines
1,641,664, Sept. 6, 1927, Electrical Sound Reproducing Apparatus
1,642,363, Sept. 13, 1927, Telephone Device
1,653,155, Dec. 20, 1927, Talking Moving Picture Equipment
1,659,909, Feb. 21, 1928, Film Protecting Arrangement
1,659,910, Feb. 21, 1928, Slot Cleaner for Phonofilm Attachments
1,680,207, Aug. 7, 1928, Radio Signalling System
1,683,451, Sept. 4, 1928, Recording and Reproducing Sound
1,687,364, Oct. 9, 1928, Radio Transmitting System
1,693,071, Nov. 27, 1928, Sound Recording Device for Movie Cameras
1,693,072, Nov. 27, 1928, Shielding for Detector and Amplifier
1,695,414, Dec. 18, 1928, Talking Moving Picture Machine
1,695,415, Dec. 18, 1928, Talking Motion Picture Record
1,701,911, Feb. 12, 1929, Acoustic Apparatus
1,710,922, Apr. 30, 1929, Motion Picture Screen
1,716,033, June 4, 1929, Producing Talking Motion Picture Films
1,718,337, June 25, 1929, Loud Speaker Motor
1,720,544, July 9, 1929, Radio Receiving Apparatus
1,722,280, July 30, 1929, Photo Electric Cell
1,726,289, Aug. 27, 1929, Diffraction Microphone
1,736,035, Nov. 19, 1929, Sound Reproducing Device
1,738,988, Dec. 10, 1929, Sound Actuated and Producing Device
1,740,577, Dec. 24, 1929, Wireless Telegraph and Telephone System
1,761,619, June 3, 1930, Sound and Picture Recording Camera
1,764,938, June 17, 1930, Producing Talking Motion Picture Films
1,766,612, June 24, 1930, Sound Reproducing Device
1,769,907, July 1, 1930, Binaural Recording and Reproducing Sound
1,769,908, July 1, 1930, Recording and Reproducing Sound
1,769,909, July 1, 1930, Talking Picture Exciting Lamp Switch
1,777,037, Sept. 30, 1930, Binaural Recording Sound
1,777,828, Oct. 7, 1930, Sound Picture Photography
1,785,377, Dec. 16, 1930, Loud Speaker
1,795,936, Mar. 10, 1931, Sound Reproducer
1,802,595, Apr. 28, 1931, Automatic Photographic Sound Reproducer
1,806,744, May 26, 1931, Talking Picture Machine Drive Mechanism
1,806,745, May 26, 1931, Sound Producing Device
1,806,746, May 26, 1931, Luminous Discharge Device
18,108, Reissued June 23, 1931, Obliterating Parts of Talking Film
1,812,687, June 30, 1931, Sound Chamber and Set Frame
1,827,283, Oct. 13, 1931, Sound Reproducer
1,834,051, Dec. 1, 1931, Microphone
1,843,972, Feb. 9, 1932, Talking Motion Picture Apparatus
1,853,850, Apr. 12, 1932, Sound Reproducing Device
1,859,435, May 24, 1932, Sound-on-Film Phonograph
1,866,090, July 5, 1932, Sound Reproducing Device
1,873,558, Aug. 23, 1932, Gaseous Discharge Device
1,885,900, Nov. 1, 1932, Talking Motion Picture Attachment
1,888,910, Nov. 22, 1932, Synchronization In Talkie Photography
1,894,024, Jan. 10, 1933, Photographic Sound Reproduction
1,897,363, Feb. 14, 1933, Luminous Discharge Device
1,929,626, Oct. 10, 1933, Soundproofing Picture Camera
1,944,929, Jan. 30, 1934, Gaseous Discharge Device
1,992,201, Feb. 26, 1935, Apparatus for Reproducing Sound-on-Film
2,003,680, June 4, 1935, Television Reception and Projection
2,026,872, Jan. 7, 1936, Television Receiving Method and Apparatus
2,045,570, June 30, 1936, Synchronizing Televised Images
2,049,763, Aug. 4, 1936, Television Sign
2,052,133, Aug. 25, 1936, Television Apparatus
2,064,593, Dec. 15, 1936, Apparatus for Reproducing Sound-on-Film
2,122,456, July 5, 1938, Television System and Method
2,126,541, Aug. 9, 1938, High Frequency Oscillating System
2,163,749, June 27, 1939, Radial Scanning Television System
2,241,809, May 13, 1941, Radial Scanning with Cathode Beam
2,391,554, Dec. 25, 1945, Aircraft Speed and Course Indicator
2,410,868, Nov. 12, 1946, Means and Method for Altitude Determination

Motion Picture Engineers Honor Dr. de Forest



Dr. de Forest with the scroll which was presented to him on the occasion of his seventy-third birthday last August. The illuminated address was presented by the Society of Motion Picture Engineers in honor of the inventor of the fundamental audion and other developments important to the progress of sound motion pictures.

Society of Motion Picture Engineers
Scroll of Achievement
Presented to
Lee de Forest
In Recognition of

His original researches which resulted in the invention of the Audion, a 3-electrode vacuum tube, destined to become a basic element in the development of telephonic communication, radio, and the sound motion picture;

His demonstration between 1921-1923 of a method of photographing a variable-density sound record on motion picture film utilizing the Photion lamp, and a method of reproducing the photographic sound record in synchronism with a motion picture by means of the Phonofilm projector which incorporated the Case Thalofide cell and a multi-stage Audion amplifier;

His courage and persistent efforts which made possible the first public showing of topical sound motion pictures in the Rivoli and Rialto Theaters in New York on April 15, 1923, and subsequently in many theaters throughout the world.

These researches and his pioneering vision of a great industry as described in a paper before members of this Society in May 1923 are recognized by the Presentation of this Scroll of Achievement by the Society of Motion Picture Engineers in this Twentieth Year of the Successful Introduction of Sound Motion Pictures.

By order of the Board of Governors
Society of Motion Picture Engineers

TO THE FATHER OF RADIO

Tributes to Dr. de Forest by Leading Figures in Radio

From Major General J. O. Mauborgne, U. S. A., Retired

Engineer, soldier, artist, inventor; chief Signal Officer United States Army, 1937-1941; technical adviser to United States delegations at several international communications conferences; radio pioneer, inventor of numerous radio devices; author of "Practical Uses of the Wavemeter in Wireless Telegraphy" and brochures on radio and cryptanalysis.

How fitting that the January issue of RADIO-CRAFT is devoted almost entirely to a tribute to Dr. Lee de Forest, commemorating the fortieth anniversary of the invention of the vacuum tube with the control grid.

Since it was my good fortune to have been a reader of *Modern Electrics* in those early days, I take more than usual interest in the tribute to Dr. de Forest, whom I have known since his art-revising basic invention of the grid, which gave us the detector, oscillator, and amplifier, and established the foundation of all later work in electronics.

Let me raise my voice in the mighty shout which issues through your technical journal in praise of and congratulations to the Grand Old Man of Wireless, not only because he will live forever in the earth's Hall of Fame, but because he is—and always has been—a real American. May he live to be a hundred, knowing that he has achieved the greatest success a scientist can hope for.

—73—

From Major General Harry C. Ingles

Chief Signal Officer, United States Army; former deputy commander, European Theater of Operations;

former chief of staff, Caribbean Defense Command; former director Army Signal School, Fort Monmouth.

It is a privilege to participate in RADIO-CRAFT'S symposium honoring Dr. Lee de Forest and commemorating the fortieth anniversary of his invention of the grid vacuum tube.

With this invention, electrons were first brought under control and the foundations of the electronics industry were laid. The development of that industry, with its startling advances and its limitless horizons, has been one of our era's most important achievements.

Engineers of the U. S. Army Signal Corps yield to no other group in their admiration and respect for Dr. de Forest, and for his pre-eminent contributions to the science of communications.

—73—

From Admiral J. R. Redman

Director of Naval Communications; member of Joint and Combined Communications Boards, Board of War Communications, State Department special committee on communications; vice-president in charge of engineering, Western Union Telegraph Co.

(Telegram)—I take great pleasure in joining with the many throughout the world in paying tribute to the achievements of Dr Lee de Forest. We stand at the threshold of an electronic era, the effect of which on human life can scarcely be envisioned. For his great achievement in successfully developing the vacuum tube, we owe a debt to Dr. de Forest that cannot be repaid.

—73—

From Brigadier General David Sarnoff

President and director, Radio Corporation of America; chairman of the board of director of the National Broadcasting Co.; brigadier general Signal Corps Reserve, U. S. Army; member of the executive committee, Institute of Radio Engineers; member of the Industry Advisory Committee of the United States Defense Communications Board; Cross of Honor of the Legion of Honor, 1940.

In two of America's great farm states, two boys grew up, one destined to create electric light and the other destined to shed enlightenment on the world through an electronic lamp. Thomas A. Edison, born at Milan, O., invented the incandescent light, and Lee de Forest, born at Council Bluffs, Ia., invented the audion. Both of these American men of science put the invisible electron to work for the benefit of mankind.

While Edison's Centennial will be observed this year, de Forest will be celebrating the fortieth anniversary of his invention of the audion, or grid, vacuum tube. The fame of both men and the value of their contribution to science and society grows greater with time.

De Forest's audion, with its stream of electrons within a vacuum, forever challenging research, has been the key to

many major advances in science and industry. The electron tube is a beacon of progress in the vast field of electronics that extends throughout radio and into many other fields such as communications, the motion picture, and the phonograph.

De Forest's great contribution to electronics helps modern science to encircle the globe by radio and to echo back from the moon by radar.

—73—

From the Federal Communications Commission

Charles R. Denny, radio lawyer, chairman, FCC; formerly general counsel, FCC; special assistant to the Attorney General; attorney, Department of Justice.

It is highly fitting that a grateful nation should take this opportunity to pay tribute to Dr. Lee de Forest. It is because of genius such as his that America has become pre-eminent in the field of electronics. Everywhere on this planet where electronics is ushering in a new era of accelerated human progress, men and women gladly acknowledge their debt of gratitude to this distinguished American scientist.

Labors are being lightened, culture is more abundant, pleasure is multiplied, new horizons are opened, all phases of civilization are enhanced because of his achievement.

The Federal Communications Commission considers it a privilege to send its felicitations to the inventor of the modern vacuum tube on the fortieth anniversary of that revolutionary event.

—73—

From Dr. E. F. W. Alexanderson

Consulting engineer, General Electric Co; former chief engineer, Radio Corporation of America; inventor of the Alexanderson alternator, multiple-tuned antenna and numerous other inventions in radio, television, electric ship propulsion, power transmission, and amplidyne control; past president, Institute of Radio Engineers; member Sigma Xi; Royal Swedish Academy of Science; decorated by King Gustav V of Sweden with Order of North Star.

When we look back upon the history of invention and industry, we find it extremely rare that one single invention has materially changed the course of events. The inventions of gunpowder and the printing press were among those exceptions. The electrical industry, the automobile, and the airplane, on the other hand, grew out of the consciousness of the scientific world without any definite starting point. There was radio and even radiotelephony before de Forest invented the vacuum tube with the control grid, but radio, as then known, was destined to become a small industry of limited usefulness. This was all changed by de Forest. With one invention, he opened up the electronics industry, which has already outgrown radio and is now on the way to become a vital factor in the power field for such purposes as power transmission, ship propulsion, and railroads, and also for industrial processes of heating and for production of materials such as aluminum and magnesium.

As an appreciation of de Forest's contribution, it may be said that he opened the gate which flooded the world with electronics.

—73—

From Dr. W. R. G. Baker

Vice-president, Electronics Department, General Electric Co.; former vice-president in charge of

engineering and manufacturing, Radio Corporation of America; president-elect, Institute of Radio Engineers; director, National Electrical Manufacturers Association; chairman, Radio Technical Planning Board; chairman, National Television Systems Committee.

I was glad to learn that an anniversary number of RADIO-CRAFT would be devoted to honoring Dr. Lee de Forest, for it gives me the opportunity of adding my good wishes to those of his many friends in America.

To those of us who have had the privilege of knowing Dr. de Forest, we find his life of achievement a great source of encouragement and strength.

I am happy to join in this tribute to Dr. Lee de Forest for his untiring service these many years.

—73—

From W. J. Barkley

Executive vice-president, Collins Radio Co.; formerly general manager, de Forest Radio Company, Jersey City, N. J.; general manager Wireless Specialty Co., one of the earliest manufacturers of radio equipment.

It was my pleasure to have been associated with Dr. de Forest for several years. Knowing that he had more to do with the progress of modern radio than any other man, as demonstrated by his invention of the audion, it was also my pleasure to be able to help coin the phrase, "The Father of Radio, while associated with him. His invention of the audion vacuum tube was the greatest development of modern times and will remain the foundation of all electronics in the years to come.

I take this opportunity of expressing to Dr. de Forest my heartiest congratulations and wishes for many more years of happiness in watching the development of electronics as the result of his outstanding work.

—73—

From Dr. O. E. Buckley

Research scientist; President (Former director of research) Bell Telephone Laboratories; member, Sigma Xi.

Hindsight is always easier than foresight, and it is now apparent that the advances being made in electron physics during the turn of the century, as evidenced by the identification and measurement of the electron, were so fundamental that the electron amplifier was inevitable in our time. Yet no one could quite see it then. It remained for de Forest, with the incentive and intuition of the inventor, to provide the all-important grid as the control element. By this one act of producing a device which would truly amplify, de Forest, more than any other one man, precipitated our great modern developments in radio and allied fields.

Representing, as I do, the laboratory to which de Forest brought his audion and where it was developed into the serviceable high vacuum tube, I join the current tribute to this great inventor with particular significance and pleasure.

—73—

From Dr. W. D. Coolidge

Physical chemist, famous as the inventor of the Coolidge X-ray tube and of the ductile tungsten electric-lamp filament; head of Hanford division, Research Laboratory, General Electric Co.; vice-president and director of research of General Electric from 1940 to 1944.

The work of Dr. Lee de Forest has had so profound and so far-reaching an influence on our daily lives that it is already difficult to see how we ever got along without grid-controlled vacuum tubes. He is eminently deserving of the satisfaction which he must feel in seeing the universal appreciation, expressed in terms of use, which his device has received.

—73—

From Prof. Frank E. Canavaciol

Consultant in electrical communications; Associate Professor of Electrical Communications, Brooklyn Polytechnic Institute; during the war, director of research and development, Universal Electronic Laboratories, New York City.

It is indeed with pleasure that I join with you and with all engineers and scientists in paying our respects to Dr. Lee de Forest on the eve of the fortieth anniversary of his invention of the grid-controlled vacuum tube.

Many citizens of Brooklyn, and some of our staff at the Polytechnic, recall the occasion when Dr. de Forest first demonstrated his audion before a gathering at the Brooklyn Institute of Arts and Sciences. In fact, our Dr. Samuel Sheldon, then Professor of Electrical Engineering and Physics at the Polytechnic, was also chairman of the Physics and Electrical Engineering group at the Brooklyn Institute. We are happy that Dr. Sheldon prevailed on Dr. de Forest to inaugurate the Electronic Age in Brooklyn.

May I also take this occasion to congratulate Mr. John V. L. Hogan, who assisted Dr. de Forest on that historical occasion.

We can never repay our debt to Dr. de Forest. His guerdon can be only our best wishes and affection. May he live long and enjoy the realization of the service his accomplishments have provided for mankind.

—73—

From Dr. J. H. Dellinger

Physicist; chief of Radio Section, National Bureau of Standards, since 1918; chief of Interservice Radio Propagation Laboratory; chairman Radio Technical Committee for Aeronautics. Former chief engineer, Federal Radio Commission (1928-29). Delegate or technical adviser to numerous international radio conferences. Author of several radio books and many shorter treatises.

Through all these years I have been one of the admirers of Dr. Lee de Forest's ingenuity and perseverance. Radio is a great debtor to this pioneer.

—73—

From William Dubilier

Famous as the inventor of the mica condenser which bears his name; holder of more than 300 patents in the field of radio, X-ray, and medical apparatus and submarine detection equipment. Author on many radio subjects.

It is most fitting that RADIO-CRAFT, one of the pioneers, is arranging the celebration of the fortieth anniversary of the greatest scientific development contributed to civilization.

Few people realize how the so-called vacuum tube has helpfully changed our mode of life and contributed toward the development and happiness of man. It has revolutionized communication—the real foundation of peace; for were it possible for all people to easily communicate with each other and exchange viewpoints, there never would be wars. It has brought to all homes the finest music, up-to-the-minute news, current events, discussions, and other educational means not previously possible. The newspapers, for the first time, have a competitor. Truly, it is the foundation for one-world government. It has changed almost every useful electrical device.

Dr. Lee de Forest, as a pioneer, has valuably contributed and opened the door to these blessings. His name is today, and for many years will be, remembered.

—73—

From Walter Evans

Vice-president Westinghouse Electric Corporation; vice-president and general manager, Westinghouse Radio Stations, Inc.

The gigantic world-wide radio broadcasting, communications, and electronics industries are undoubtedly the greatest tribute which can be paid to Dr. Lee de Forest for his brilliant invention of the three-element audion tube. The significance of these industries to nations and to individuals stands as a living monument to Dr. de Forest's pioneering efforts.

Because this invention has been so basic to the activities of our people at the Westinghouse radio stations, and the industrial electronics and home receiver divisions, I join with them in sending our special appreciation and good wishes to Dr. de Forest for his vital contribution to the radio-electronics industry.

We, in turn, join all the men and women of Westinghouse in expressing our personal gratitude to Dr. de Forest for the individual benefits and pleasures made possible by his great invention.

—73—

From Dr. W. L. Everitt

Engineer, physicist, former chairman FCC; head of the electrical engineering department, University of Illinois; wartime director Operational Research Staff, Office of the Chief Signal Officer, U. S. Army; ex-president Institute of Radio Engineers; member Sigma Xi; author of technical works, including "Communication Engineering," and (editor) "Fundamentals of Radio."

It is seldom that great pioneers are able to see, within their own lifetime, the development of a great industry founded upon their contributions. By now there can be no doubt that in a short list of the great forward advances in technology made by man, the development of means for controlling the flow of current in a vacuum tube, which was made by Dr. de Forest, must be listed prominently. To Dr. Lee de Forest, the world of the future as well as that of the present owes a great debt.

—73—

From Dr. Alfred N. Goldsmith

Engineer, editor, and author. Former chairman of the board of construction engineers, National Broad-

casting Co.; director of research, chief broadcast engineer, vice-president, and general engineer, Radio Corporation of America. Now editor of Proceedings of the Institute of Radio Engineers; chairman of the sections on radio and motion pictures, American Standards Association; vice-chairman, Radio Technical Planning Board.

It is occasionally the good fortune of a man to create a device which opens practically unlimited vistas of accomplishment to his fellow workers, and which benefits civilization to a major extent. Dr. Lee de Forest, in producing the three-element electron tube, thus provided a powerful stimulus to his co-workers—an instrument of amazing potentialities to the fields of electrical, communications, and electronic engineering, and a source of untold benefits to the world at large.

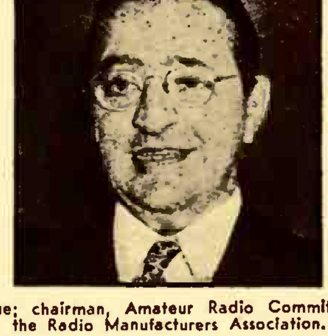
It is difficult, even now, to appraise fully the amazing scope and value of the electron tube. It may well require decades or centuries fully to explore its capabilities.

But in the meantime historians, usually given to recording the day-by-day wrangles of governments and their representatives, might well turn aside to the more wholesome task of honoring such men as Dr. de Forest who constructively create the bases of our civilization rather than the elements of its destruction.

—73—

From William J. Halligan

President, The Hallicrafters Co.; senior vice president, Army Signal Association; president, The Signal



League; chairman, Amateur Radio Committee of the Radio Manufacturers Association.

I had the pleasure of assisting in the celebration of Dr. Lee de Forest's seventy-third birthday on August 26. Fittingly enough, this birthday party was held in Chicago, where he began the experiments which resulted in the audion tube, one of the greatest inventions of all history.

Those of us in the radio industry owe him a tremendous debt, as do all in the allied electronics industries. It is a great privilege to participate in this issue of RADIO-CRAFT, which you have arranged in tribute to Dr. de Forest and his many achievements.

—73—

From R. V. L. Hartley

Famous as the inventor of the fundamental Hartley circuit. General communications engineer and theoretical research worker, at one time in charge of all wire-transmission research for Bell Telephone Co. At present theoretical consultant, Bell Telephone Laboratories, in which capacity he was instrumental in developing applications of servo mechanisms to radar and fire control during the last war.

We might try to evaluate the significance of Dr. de Forest's invention of the three-element vacuum tube by visualizing how things would be now if the invention had not been made. This, however, would be as vain as trying to predict the future. But we can picture with certainty many things which would not now be. Merely to catalog these would amply justify the conclusion that when Dr. de Forest added the grid to his tube he also added another dimension to the electric arts.

—73—

From R. A. Heising

Radio and patent engineer; best known as inventor of the Heising modulation circuit for radiophone transmitters; radio research engineer, Western Electric Co., 1914 to 1925, Bell Telephone Laboratories, 1925 to 1944; past president, Institute of Radio Engineers; designer and developer of ship-to-shore, trans-atlantic, and other radiophone circuits.

It is comforting to see the contemporaries of Dr. Lee de Forest of the days of the invention of the audion rising to pay tribute to that great inventor. They indeed understand the difference between the world before and after that important happening. While most of the world takes his contributions along with liberty, free speech, and the ballot, as though they were natural phenomena instead of things worked or fought for, his friends of the early days are groping to find words to express to him their appreciation. May suitable words be uttered while his ears still hear, and stimulate him in work and health for years to come.

—73—

From John V. L. Hogan

Consulting engineer, pioneer of high-fidelity broadcasting; president Interstate Broadcasting Co. (WQXR); special assistant to the director, Office of Scientific Research and Development; past president, Institute of Radio Engineers; inventor of many radio and facsimile devices; author of "Outline of Radio" and shorter works; formerly assistant to de Forest and to Peter Cooper Hewitt.

My pleasure in giving Lee de Forest maximum credit and recognition for his constructive work in radio is increased by the fact that, while I was his chief (and only!) laboratory assistant during the winter of 1906-07, I attended the birth of the very first grid audion. Having seen the conception and nativity of that little glass baby, I nursed it through its earliest life, and made its first characteristic curves. I am happy that Dr. de Forest is still with us, and I want to congratulate him again, in this fortieth year, on his invention of the grid audion.

—73—

From I. J. Kaar

Manager Receiver Division, Electronics Department, General Electric Co.; chairman, Institute of Radio Engineers Committee on Television; chairman, Radio Manufacturers Association Committee on Television Receivers.

I doubt if anyone alive today can possibly visualize the magnitude and the effect upon humanity of Dr. de Forest's invention of forty years ago. The accomplishment and the things which have been built upon it are almost beyond comprehension. It is a privilege indeed to do homage to the Grand Old Man of Radio.

—73—

From Charles F. Kettering

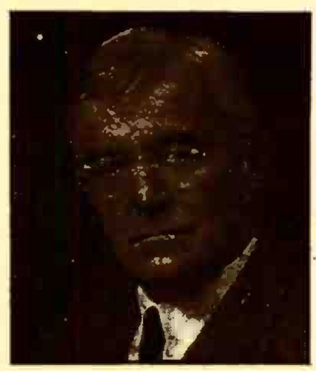
Engineer, manufacturer, inventor, and educator; general manager Research Laboratories Division and vice-president and director of General Motors Co.; inventor of automatic starting, lighting and ignition systems; chairman National Inventors Council.

Perhaps the most important date in the history of electronics is December 31, 1906, when a young experimenter named Lee de Forest inserted a third electrode in the form of a grid between the cathode and anode of a vacuum tube. The spectacular growth of electronics to an enormous industry employing over a million workers and benefiting untold millions of people in all parts of the world may be said to have begun on that date. Dr. de Forest's invention of the triode tube not only solved certain problems of itself, it also acted as a stimulus to the efforts of hundreds of later inventors who devoted their lives to improving it and adapting it to an ever-increasing number of uses. Even today the full extent of its utility and value has only been scratched. This ability to illuminate the path ahead is one of the characteristics of a truly great invention. To say that the three-element tube possesses this characteristic to a degree unique among modern inventions is the enormous tribute we must pay to Dr. de Forest.

—73—

From Dr. Irving Langmuir

Chemist; inventor of the condensation high-vacuum pump which made "hard" radio tubes possible; worked in the development of gas-filled tungsten lamps, electron discharge apparatus, molecular



films, submarine detectors, and other projects; associate research director, General Electric Co.; past president, Institute of Radio Engineers, American Association for the Advancement of Science, American Chemical Society; member Sigma Xi.

Lee de Forest, in discovering that an electric current in a vacuum tube can be controlled by means of an interposed grid, laid the foundation for an extension of man's senses—an increase in speed and in sensitivity of many millionfold. The revolution has been as great in its way as that which may now be envisioned in other fields through our new control of nuclear power.

—73—

From George Lewis

Assistant vice-president, International Telephone and Telegraph Corporation and Federal Telephone and Radio Corporation; radio officer at New York Navy

Yard, 1915, and radio officer, design division, Bureau of Steam Engineering (later Bureau of Engineering) U. S. Navy, Washington.

I recall one of the many valuable contributions of Dr. de Forest to the advancement of the then infantile vacuum tube art in 1917, when I was chairman of the Vacuum Tube Committee for the Navy. This committee, probably the first official vacuum tube committee in the world, was set up when America entered World War I.

There were few vacuum tubes in the world then, but the Navy had experimented with them since 1913. The tubes, due to imperfect vacuum, had unreliable sensitivity and would glow with a bluish light—operators learned to pluck a tube to vibrate the wing (plate) and achieve "twilight zone blue" for greater sensitivity.

Dr. de Forest met with the committee and set up uniform tests for vacuum tubes. It was due primarily to his counsel, backed by his knowledge in the field which he himself had opened and was tirelessly exploring, that the Navy was able to take steps which not only increased the efficiency of their communications at the time but led eventually to their present high development in electronics.

—73—

From Dr. Frederick B. Llewellyn

Research engineer and inventor; president, Institute of Radio Engineers, 1946; consulting engineer, Bell Telephone Laboratories; international authority on the design of vacuum tubes used for communication and electronic control purposes; inventor of ultra-high-frequency oscillator tubes and designer of stabilized oscillating circuits.

Great things are often simple ones as well. The introduction of a grid of wires between the cathode and anode of a two-element vacuum tube is simple in itself, but the consequences have been breath-taking in their effect. The grid changed the tube from a nonlinear circuit element into a device capable of accurate control of power. Alone and uncontrolled, power is useless and may be actually harmful, while, in contrast, controlled power is the foundation of technical civilization. The grid turned the vacuum tube into the versatile control device that has brought about technical advances previously inconceivable.

To the man who first introduced this simple but far-reaching change in the vacuum tube, to Dr. Lee de Forest, on this occasion of the fortieth anniversary of the audion, I am delighted to pay tribute.

—73—

From Donald McNicol

Editor, engineer, and author. Past president (1926) Institute of Radio Engineers. Radioman since 1900. Author of "American Telegraph Practice", standard text on telegraphy. At present technical consultant, "Telegraph and Telephone Age", and general consultant in the communications field. His latest book, "Radio's Conquest of Space", has just been published.

During the years when de Forest was busy fashioning the first audions, he struggled, often alone, with limited funds and with little encouragement. It is of interest to note some of the outstanding scientists who were de Forest's contemporaries in 1907 when the audion was about to emerge from the laboratory and when he was 34 years of age: M. I. Pupin was 49; Nikola Tesla, 50; Elihu Thomson, 54; Oliver Lodge, 56; J. A. Fleming and A. H. K. Slaby, 58; H. von Helmholtz, 57; H. A. Rowland, 59; Alexander Graham Bell, Thomas A. Edison, and E. J. Houston, 60. Marconi was 33, and John Stone, 38. The electrical achievements of these scientists will be recounted and written about thousands of years from now, as has been true of the work of the ancient philosophers.

For radio needs the audion at first was not perfect. It arrived somewhat after the manner of the stork's deliveries—well endowed with the vigor to howl lustily. But the call that soon went out to pacify the howler and suppress the howls launched inquiries which spawned the scores of inventions that prepared the way for the electronic age.

—73—

From L. K. Marshall

President, Raytheon Manufacturing Co.; Trustee, Tufts College.

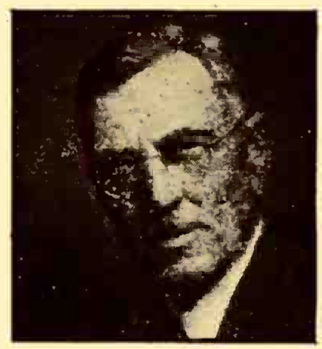
When Lee de Forest saw the possibilities of making an electron relay out of an ordinary incandescent electric light bulb by adding two more elements, he may have foreseen what tremendous and awe-inspiring developments would follow. His energies then were concentrated upon a new and better method of controlling the flow of an electric current. The realization of the method he visualized was revolutionary in itself. His success in this objective unlocked the secret which made possible an entirely new age, a skyrocketing of the living standards of the whole human race, and vast, ever-expanding new industries.

His brilliant achievements are recorded in history and will forevermore serve as an inspiration to scientists and engineers the world over.

—73—

From I. F. Mouromtseff

Transmission tube research engineer; assistant to manager, Westinghouse Electronics Engineering Department.



Beyond any doubt, de Forest's audion began *a new era* of radio-electronics and, through many subsequent developments, also became the heart of industrial electronics. Its value as amplifier of the most minute currents and voltages in an unheard-of proportion was appreciated not only by the radio receiver designers but also by the telephone companies and resulted in long-distance wire telegraphy and long-distance telephony.

But its greatest worth lay in the possibility of generating, in simple circuits, currents from the lowest audio to the highest radio frequencies measured in millions of cycles per second. With modulation applied to the grid of the audion, radiotelephony became an accomplished fact. With unprecedented ease it solved all problems on which many experimenters had been working with no appreciable success in their endeavor to realize radiotelephony by means of the Poulsen arc or high-frequency rotating alternators.

As in every great invention or discovery, there is in de Forest's epochal invention an element of inspiration or revelation (frequently called "act of subconscious mind"). This is not the result of painful logical thinking and cut-and-try practice, but a sudden message from Mother Nature flashing through the mind of the inventor. Logical work and scientific analysis usually come later in elaborating the details and explaining the observed facts. In de Forest's case the inspiration was the idea of interposing a grid between the cathode and anode of a tube; this made the whole difference between "to be" and "not to be." In all truth, Dr. de Forest is entitled to the honorary degree of "Father of Radio-Electronics."

From E. A. Nicholas

President, Farnsworth Television and Radio Corporation; former vice-president and member of the advisory board, Radio Corporation of America.

In a year in which we have witnessed a flash of light across the world, representing perhaps the ultimate application of science to destruction, it is most fitting that we pay honor to one who has done so much for the *constructive* progress of science.

The harnessing of the electron has proved one of the mightiest forces in the advancement of human welfare. For Dr. de Forest's leadership, his inspiration and his magnificent contributions to science, we are deeply grateful.

On this anniversary of the birthday of the three-element vacuum tube, we join in wishing for him many happy returns of the day.

—73—

From Louis G. Pacent

Consulting engineer; president, Pacent Engineering Corporation; pioneer manufacturer of radio parts and equipment; formerly consulting engineer on talking-picture sound equipment, Warner Brothers Pictures, designing for them the first all-power-operated motion-picture sound equipment. Author of a number of books and papers on radio subjects.

On this occasion of the fortieth anniversary of the invention of the electron tube by Dr Lee de Forest, I join with the many friends and admirers of this great genius in paying homage.

I recall my first meeting with Dr. de Forest at his laboratory in the Metropolitan Life Building shortly after his tube was announced to the world, and although he saw clearly its many uses, his achievement was borne without self-glory. Since that time, I had the good fortune of seeing a good deal of him, and discussing early radio problems. From these meetings I acquired a great amount of radio sense. In 1917 he spoke at the Pratt Institute Engineering Alumni dinner, and made many predictions which have come to pass.

It is therefore proper and fitting that on this occasion we honor a great man, whose achievements and accomplishments are outstanding in furthering the progress of not only the radio art but also humanity at large.

From J. R. Poppele

President, Television Broadcasters Association; vice-president, chief engineer and supervisor of programming, Bamberger Broadcasting Service; pioneer broadcaster (chief engineer of WOR since its opening).

Dr. de Forest is perhaps the foremost exponent of the electronic art. His developments have made possible not only advancement of wireless telegraphy and wireless telephony, but radio broadcasting and the newest communication medium of all-television.

The development of his vacuum tube made possible the first organized attempt to fly the Atlantic. It was the development of his vacuum tube that made possible transoceanic transmission of photographs.

Today everyone's life is touched by the magic of electronics, which employs the fundamental tube developed by Dr. Lee de Forest: persons at sea depend upon radio for safety; persons hard of hearing have been aided immeasurably by electronic hearing aids; people undergoing operations are more certain of recovery through use of the electronic knife and electronic diathermy; the farmer in the fields owes much of his knowledge of modern world affairs to radio; the airplane is guided by radio; the wholesale merchant counts packages coming down belt lines by means of the electronic eye.

And now, thanks to Dr. Lee de Forest's pioneering, the greatest entertainment on Broadway and Hollywood will be brought to everyone's home through the great magic of television. We salute Dr. de Forest—a great inventor and a warm, human individual.

—73—

From Haraden Pratt

Communications engineer; vice-president, chief engineer, and director, Mackay Radio Corp.; vice-president and director, Federal Telephone and Radio Corp.; chairman of the Radio Technical Planning Board, 1946; chairman of Panel 8 (Radio

Communications) of the Radio Technical Planning Board; past president, Institute of Radio Engineers; committees on radio engineering standards; member, Sigma Xi.

(Continued on page 129)

Resolution

Whereas, the science of electronics owes a deep debt of gratitude to the fertile mind of Dr. Lee de Forest and his epoch-making three-element vacuum tube, and

Whereas, the acknowledged "Father of Radio," from his invention of the "grid" in 1907 to the present day, has continued his rich contributions to the expanding electronic art, and

Whereas, Dr. de Forest has played an important rôle in television progress as a natural sequence to his pioneering in sound motion pictures,

Therefore, Be It Resolved that the television art and industry, expressing itself through the Television Broadcasters' Association, Inc., record its affectionate greetings to the "Father of Radio" on the occasion of the Fortieth Anniversary of the "Audion," and

Be It Further Resolved that this Association hereby pays its warmest respects and deepest gratitude to this great scientist and inventor whose unending pioneering has helped bring about the realization of television and its immense possibilities toward Uniting All People.

By Order of the Board of Directors

(SEAL) President Secretary-Treasurer

Dated this 31st day of October in the year 1946.