

Lee de Forest

WHY THIS ARTICLE?

August 26, 1973 marks the 100th anniversary of the birth of Lee de Forest. And it is in recognition of the many contributions of this electronics pioneer that this article appears.

In this age of solid-state, after 25 years of the transistor, many of us are inclined to underestimate the importance of the fundamental invention of electronics, the vacuum tube. Yet before the 25 years of the transistor, we have had 40 years of the tube.

Indeed, if we had been forced to continue with the crude methods of transmission and reception of the pre-tube era, it is unlikely that radio communications would have developed enough to make the research that led to the transistor's invention possible.

So, as de Forest is acclaimed as the Father Of Radio, his vacuum tube can be considered the progenitor of the transistor—the father of solid state.

De Forest's most important invention has, unfortunately, overshadowed his other accomplishments, which would have made him probably the most important figure in American radio communications without it.

Most of the more important "wireless" stations now operating along the Atlantic coast were established by him. His "radio knife" of electronic surgical scalpel is well known in the medical field and our present talking movies follow very closely the principles of the de Forest Phonofilm.



The Audion—the vacuum tube triode; telephone dialer; and an electronic scalpel

by FRED SHUNAMAN

LEE DE FOREST—LIKE TOO MANY OTHER figures in the history of electronics—is already becoming a victim of neglect by those who write the histories of radio. Given the honorific "Father of Radio" for his invention of the Audion amplifying vacuum tube, practically none of his other work is mentioned—nor remembered. And illiterate historians—because of a superficial resemblance between the two devices—are prone to describe even de Forest's most important invention as a mere improvement on the Fleming valve rectifier. Yet—invention of the vacuum tube aside—de Forest was the prime figure in the development of radio communication in the United States.

Graduating from Sheffield Scientific School, Yale, in 1899, he had chosen for his Ph.D. thesis, "The Reflection of Hertzian Waves from the Ends of Parallel Wires." Marconi was then demonstrating his equipment in England (where he was denounced by some as using the apparatus of Lodge), Popov was experimenting between his station at Kronstadt and ships of the Russian Navy, and Ducretet had sent signals from the Eiffel Tower in Paris to the Pantheon,

4 kilometers distant. Tesla had (in 1898!) actually demonstrated remote radio control in Madison Square Garden, New York City. There was enough "wireless" in the air to fire the imagination of the newly hatched Ph.D., and he immediately sought employment in the communications field, meanwhile starting to work on a detector of his own, which he called the Responder.

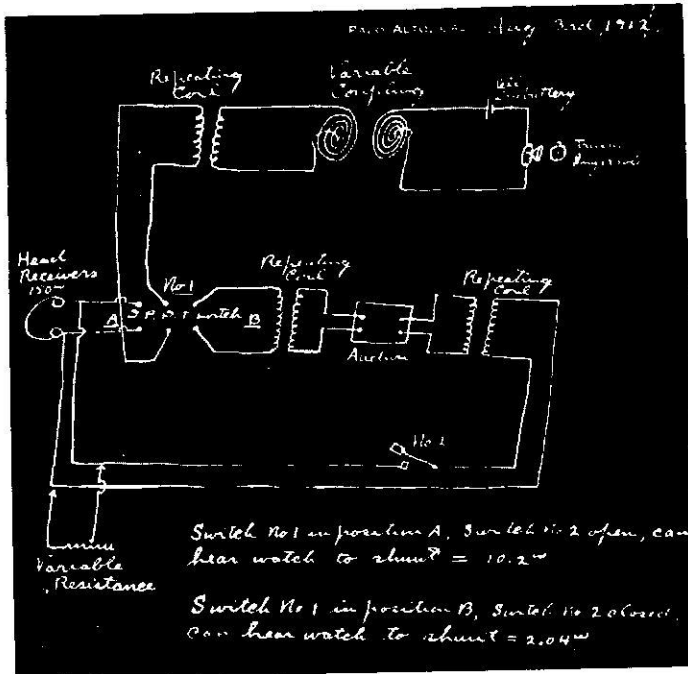
This first de Forest detector was patterned on a principle described by the German scientist Aschkinass. A drop of liquid (de Forest spent many weeks trying to find the perfect one) between two contacts carried current until the arrival of an electric wave. Then its resistance rose suddenly, due to the breakdown of "little trees and bridges" of metal in the liquid. Its great weakness was that after a time—ranging from minutes to days—it would "clog" and pass current continuously.

Working in Chicago, first for Western Electric, then part-time as assistant editor of the *Western Electrician* and receiving some support from a fellow-worker, Ed Smythe, de Forest brought the Responder to a point considered usable, and—jointly

100th Anniversary

→ SCHEMATIC OF THE FIRST AMPLIFIER ever constructed. "Repeating coil" is an old telephone term for transformer. The circuit was made so strength of the signal can be varied and has a variable resistor shunt for phones so amplified signals could be compared.

← HUGO GERNSBACH, founder of this magazine, as he presented in 1947, a copy of the special "de Forest" issue to Dr. de Forest. The Jan. 1947 issue of Radio-Craft marked the 40th anniversary of the triode vacuum tube.



WHAT WAS THE AUDION, REALLY?

What actually was this Audion, de Forest's most important invention? Was it—as some say—simply an improvement on the Fleming valve ("de Forest inserted a third electrode") or was it an entirely separate invention?

The answer is that the Fleming valve and the de Forest Audion are not only two distinct inventions, but belong to two different families of detection devices. The Fleming valve is a rectifier. As such, it takes its place with Fessenden's Wollaston wire detector and the crystal detectors of Pickard and Dunwoody. The de Forest Audion is a relay—a device that uses the radio signal to trigger or control a greater amount of power supplied by a local source (de Forest's "B" battery). It belongs to the same family as the Branly coherer and de Forest's earlier Responder.

Because the Audion can control a greater amount of power with a smaller amount, it can amplify, and can also be made to regenerate. Oscillation and radio transmission are, of course, a product of that effect.

Dr. de Forest experimented for a number of years with devices fundamentally similar to the Audion, using the ionized gases of Bunsen burners. In 1904 he turned to partially evacuated lamp bulbs to produce the same ionization. It is quite possible that the idea of using a lamp bulb may have been suggested to him by the Fleming valve. It is equally possible that, since both were working with glass bulbs in 1904, that they may have been working in ignorance of each other's efforts.

But even if de Forest had known of Fleming's valve, and (as an extreme case) had obtained one of them, opened it, placed his grid in it and resealed it, it would still have been in no sense a modification of nor an improvement on the Fleming valve, but a separate and independent invention. Lee de Forest was persuaded of the importance of ionized gas, found that a partly evacuated bulb gave him an opportunity to work with ionized gas. It was a more reliable and rugged device than his earlier open flame devices. Fleming's rectification did not enter into his calculations—in fact one of his earliest patents on what we now know as the Audion was entitled "A Device for the Amplification of Feeble Currents."

the first radio signal jamming; an automatic
are all the inventions of this man

with Smythe—took out a patent on it.

The famous "gas mantle" incident occurred during this period. Smythe and de Forest noted their spark discharge caused the gaslight to brighten, and devised an interesting theory to account for it. When they found it was simply the sound waves from the spark gap that caused the effect, de Forest refused to abandon the "ionized gas" theory. Finding that a gas flame was, indeed, a crude detector of wireless signals, he patented during the next several years some 11 devices using ionized gas, the last one being the Audion.

Having developed equipment that would work reliably over at least four miles, de Forest went East with the idea of covering the upcoming International Yacht Races by wireless for the Associated Press. But Marconi had already signed a contract with them. After some trouble, de Forest got a contract from the Publishers Press Association, loaded his equipment on a tug, and went out to write a new page in the history of wireless.

That new page was the discovery of interference. Both Marconi and de Forest had heard of tuning, but neither considered that refinement neces-

sary. They jammed each other hopelessly, and the race reports were transmitted to shore—wirelessly, sure enough—by wig-wag flags.

De Forest in business

Organizing a small firm, the American Wireless Telegraph Co., to raise capital to improve his apparatus, de Forest struggled to keep alive through the rest of the year. In January 1902 he met the first of the "businessmen" destined to move the de Forest fortunes into affluence and bankruptcy not once, but three times. Abraham White was a highly successful professional promotor, who was convinced there was money in the glamorous wireless field. Not as critical as de Forest's technical friends, he asked only that the equipment show up well enough to persuade investors to buy stock. Absorbing de Forest's company, he formed the American de Forest Wireless Telegraph Co., and de Forest found himself with capital to work with—plus a regular salary of \$30 a week!

His first development was an ac-operated spark transmitter, with a "high-frequency note" of 120 Hz, which produced a sharper and easier-

to-read signal than the low notes of the dc interrupters previously used. He then set up stations in lower Manhattan and Staten Island, and exchanged messages between them. The Navy became interested, though continuing to depend in the main on German apparatus, which could print messages out on tape. They bought de Forest equipment, both for shipboard use and to

Aerophone, an arc telephone with which he had been experimenting, and \$1,000 in cash.

The radiophone

Organizing the de Forest Radio Telephone Co., almost without capital, he moved into the Parker Building, New York City (now famous as the birthplace of the Audion) and started to make radio telephones. During 1907 and 1908 he installed equipment on two dozen Navy craft for a round-the-world cruise. Because of hurried installation and untrained operators, results were good only in odd cases, according to de Forest. But even these results persuaded Admiral Evans of the value of the radiophone, and he became a strong supporter of it.

In 1908 the Italian government bought four sets of equipment for use in warships, and a little later the British bought two, after tests showed reliable communication over more than 50 miles.

Amplification and regeneration

Working on a method of recording signals, de Forest found they were often too weak to be recorded properly. One of the earliest patents on the Audion was entitled "A Means for Amplifying Feeble Currents," and with two assistants, Charles Logwood and Herbert van Ethen, de Forest set about to make it earn the title. But the Audions of that day would glow blue and stop amplifying if more than a few volts were applied to the plate. Realizing that the trouble was probably too much gas (de Forest was still sure that *some* gas was necessary for Audion action) he had a local X-ray manufacturer evacuate some tubes to a higher vacuum. The new Audions would take 120 volts, and were immediately successful as amplifiers.

While working on the amplifier, de Forest and his assistants one day connected the output of the second stage back to the first. That historic day, August 16, 1912, was the birthday of feedback, regeneration and oscillation. They heard (and described in van Ethen's notebook) a high musical note as a result of the feedback experiment, and noted that it could be varied by varying the capacitance or inductance in the circuit. Further experiments on a day when only one good Audion was available—showed that the same results could be obtained with a single tube—self-regeneration or oscillation.

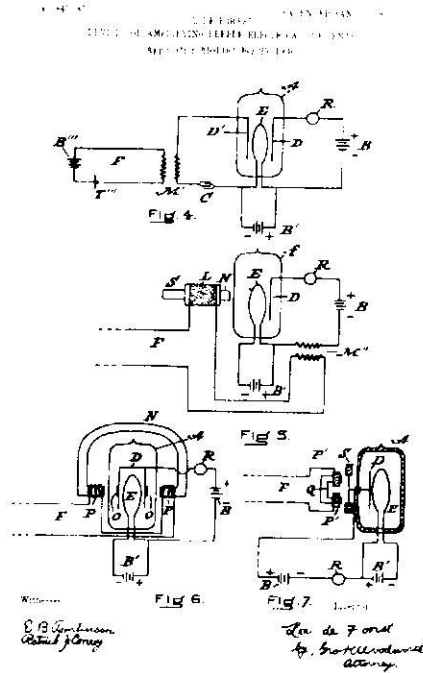
Years later, when Armstrong claimed the invention of regeneration, van Ethen's notebook was the instrument that proved de Forest's priority.

De Forest decided to go East and demonstrate his new amplifier to "The

Telephone Company" (AT&T and its subsidiary Western Electric) who had long been searching for a way to boost signals on long-distance telephone lines. He was encouraged by the attitude of the Telephone Co. and decided to remain East. But after nearly a year of waiting, with no money coming in from the North American Wireless Corp., de Forest found himself literally broke, with his watch in pawn.

At this time he was approached by a young lawyer, Sidney Meyers by name, who said he represented parties interested in the Audion as an amplifier. He would not reveal his backers, only pledging his "word of honor as a gentleman," that he did not represent the Telephone Co. He offered \$50,000, a much smaller sum than de Forest thought he could get for the amplifier rights. But his company, owner of the patents, was in a precarious position and might find company assets, including the patents, put up at auction to satisfy creditors. And de Forest himself was on the verge of starvation. So he agreed, only to find a few weeks later that his customer was indeed the Telephone Co., and that its directors had allegedly been prepared to pay as much as half a million dollars for the rights he sold for \$50,000.

The deal was not as bad as it has been represented; de Forest did not sell the Audion patent—simply the right to use it as an audio amplifier on wire lines.



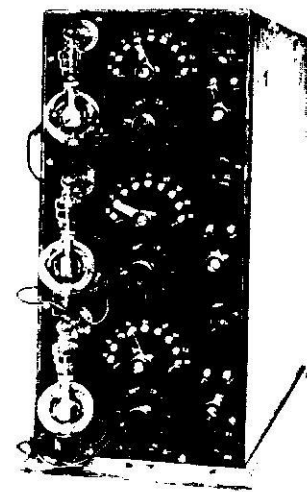
PATENT DRAWINGS used to illustrate the principles of an early vacuum-tube amplifier patented by Dr. Lee de Forest in 1907.

outfit two new stations, one at Washington and one at Arlington. This kept the de Forest plant working full-time through the winter of 1902-03.

In 1903, de Forest finally succeeded in reporting the International Yacht Races by radio instead of light waves. 1903 also saw the introduction of wireless to Canada. The first press station, with which the *Providence Journal* kept in contact with Block Island, and the first commercial wireless telegraph—between Nome, Alaska, and Fort St. Michael, a distance of 107 miles—were also installed that year.

The year 1904 was even better, with de Forest's exhibit the main attraction of the St. Louis World's Fair, and a contract for five powerful Government stations—at San Juan, in Puerto Rico; Key West and Pensacola, Florida; Guantanamo, Cuba; and Colon, in the future Canal Zone.

In 1906 de Forest first ran afoul of his stock-selling associates. White and his pals gutted the company by organizing a new outfit, United Wireless, and transferring to it all the assets and none of the debts of the older company. Quitting the organization in disgust, de Forest turned in all his stock, asking nothing but the patents on the Audion and on the



THIS THREE-STAGE AUDION AMPLIFIER was first built in 1912 by the Federal Telegraph Co. (predecessor of ITT) during the period that de Forest was the head of the research department. The earliest known commercial cascade amplifier, it had a gain of 120. It was first demonstrated to the United States Navy in September of 1912.

A fraud case came to trial late in 1913. Some of the stock-jobbing directors of the company were found guilty and sent to Federal prison. The jury found de Forest innocent, even though the prosecutor produced unassailable proof that de Forest had

claimed it would soon be possible to send the human voice across the Atlantic with what the prosecutor described as "a queer little tube that had proved worthless—not even a good lamp!"

In 1914 de Forest ran into new legal trouble. The Marconi Co. charged that the Audion infringed the Fleming valve patent, and won the case. But the court also decided that

came the first newscaster, announcing the results of the 1916 Presidential election (four years before KDKA's heralded broadcast). The High Bridge station closed at the outbreak of World War I.

By 1916 the Telephone Co. had decided it needed still more rights in the Audion, and re-opened negotiations. Finally, de Forest sold all rights in the Audion and in radio service for

duced by de Forest Phonofilm in 1925. Phonofilm had some 34 theaters "Wired for sound" at that time, but competition was strong and the movie moguls moved to another system. He retired from the field in 1929, with only \$60,000 as a settlement from one of his commercial and legal competitors.

To get capital for his sound-on-film work, he had sold control of the de Forest Radiotelephone and Telegraph Co. to a group of Detroit automobile capitalists. He was hired by them as a consulting engineer, and was able to watch the company go downhill to ultimate absorption by RCA. Thus the last of the de Forest companies—like the first—finally became part of RCA.

The busy period of de Forest's life ended with sound-on-film. In the '30's and '40's, he experimented with television, devising a color filter hardly larger than the tube screen, instead of the bulky and alarming color wheel.

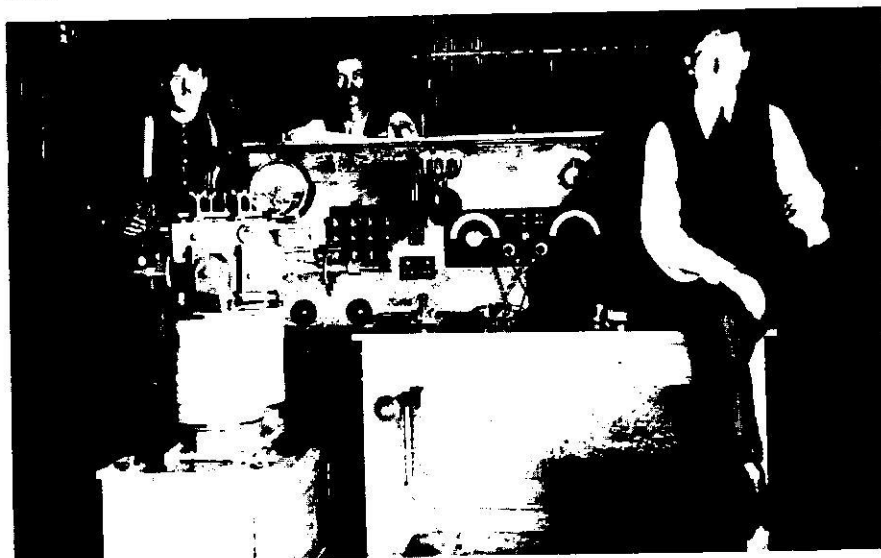
In his work with television he also developed his last important invention, radial scanning, patented in 1941. He disposed of the patent to RCA, at a lower price, he said, than he would have if he could have foreseen radar (only a year or so later) and the PPI display.

Continuing to experiment and invent, he again found himself not oversupplied with funds. A contract entered into in the '40's with the Bell Telephone Laboratories supplied him with means to equip a new laboratory and eased his financial situation considerably. In return, he was to license Bell under all patents that might be granted him.

Dr. de Forest remained more or less active until his retirement in 1958, when he was 84 years old. His last patent—on an automatic telephone dialing device—was issued in 1957. He went to France the same year, to receive the Cross of the Legion of Honor, which was added to a number of earlier honors, including the degree of Doctor of Science from both Yale and Syracuse universities, and awards from various learned institutions and organizations. He died June 30, 1961, after a long illness.

REFERENCES

- Carneal, Georgette, *Conqueror of Space*, 1930.
- Archer, Gleason L., *History of Radio*, 1938.
- MacNicol, Donald, *Radio's Conquest of Space*, 1946.
- Radio-Electronics*, January, 1947, Special de Forest issue. Several articles and items.
- de Forest, Lee, *Father of Radio*, 1950.
- New York Times, July 2, 1961, pages 1, 32. Obituary and short biographical sketch.



SOUTH SAN FRANCISCO STATION of the Federal Telegraph Co., as it appeared in 1912. The station is fitted for duplex operation as developed by Dr. de Forest, with two identical 30-kW transmitters taking turns on one antenna.

the Audion patent was valid as well. The result was that neither de Forest nor Marconi could make Audions. The resulting confusion lasted until the Fleming patent expired in 1922, and produced some absurd effects. For example, Marconi had licensed the Moorehead Co. in San Francisco to make Fleming valves. So de Forest's company ordered Audions from Moorehead, and sold some to Marconi!

Also in 1914, Sidney Meyers appeared again—in the open this time. The Telephone Company was interested, he said, in securing radio signaling rights in the Audion, and offered \$10,000 for such rights. More cautious this time, de Forest asked for \$100,000, and obtained \$90,000. The de Forest company retained the right to manufacture Audions "for amateur and experimental use."

In 1915 de Forest used the Audion to make the first music synthesizer, selling the patent to Wurlitzer.

Broadcasting established

In the winter of 1909-1910 de Forest had pioneered broadcasting by putting the Metropolitan Opera on the air—for one performance. Now he began a regular broadcast service from his High Bridge station. Because he transmitted phonograph records, lent by Columbia, he claims the title of world's first disc jockey. He also be-

came the first newscaster, announcing the results of the 1916 Presidential election (four years before KDKA's heralded broadcast). The High Bridge station closed at the outbreak of World War I.

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De Forest Phonofilm

De Forest next turned to the movie sound field. He had already experimented with magnetic wire recordings synchronized with the film, but now decided to try to put the sound on the film itself. The world's first talking picture, a Swedish film called "Retribution" in translation, was pro-