Fig. 135

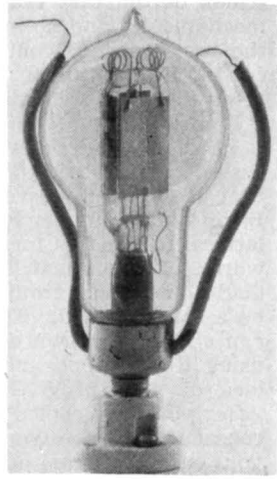

Fig. 136

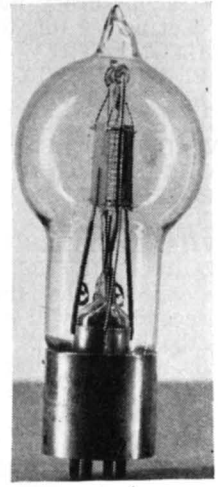

Fig. 137

THE SAGA OF THE VACUUM TUBE

By GERALD F. J. TYNE
Research Engineer, N. Y.

Part 12. The period of increased activity in the wireless industry with Lee de Forest's development of suitable oscillator and detector tubes.

WITH the money received from the sale of the telephone repeater rights on the Audion to the Telephone Company, de Forest went back to his old laboratory in the High Bridge section of New York City and resumed his investigations as of old. Before long, the laboratory was again in operation and things were progressing as before. In the discovery of the ability of the Audion to produce oscillations, little had been learned concerning its operating characteristics as an oscillator, or generator of alternating currents. De Forest, once more free from want, at least temporarily, began work on the problem of making the Audion give high-frequency output in useful quantities.

His peace of mind was not for long, however. One of the by-products of the wireless boom of 1906-1907 and the stock-jobbing schemes previously mentioned was the indictment of de Forest and some of his associates early in 1912. They were charged with using the mails to defraud, in connection with the sale of Radio Telephone Company stock. At the time de Forest demonstrated the Audion before the officials of the Telephone Company, he was free on bail of $10,000 which had been furnished by Beech Thompson, president of the Federal Telegraph Company. De Forest and his associates were brought to trial in late November of 1913. The trial ran for six weeks. So little were the potentialities of the Audion realized at that time that the indictment charged them with using the mails to defraud the public by selling stock "in a company incorporated for $2,000,000, whose only assets were de Forest's patents chiefly directed to a strange device like an incandescent lamp, which he called an Audion, and which device had proven to be worthless." This in 1912!

The Federal District Attorney, Robert Stephenson, in summing up his case said that de Forest had said[168] ". . . in many newspapers and over his signature that it would be possible to transmit the human voice across the Atlantic before many years. Based on these absurd and deliberately misleading statements of de Forest, the misguided public, Your Honor, had been persuaded to purchase stock in his company—" And yet, only two years later this feat was accomplished by the A. T. & T. Company engineers, using improved electronic tubes, based on the Audion which the overzealous District Attorney held up to such ridicule! Truly Mr. Stephenson's face must have been red!

The jury rendered its decision on New Year's Eve, December 31, 1913, seven years to the day after the grid was first inserted in the Audion. De Forest and his friend and patent attorney, Samuel Darby, were acquitted. Two of their associates were found guilty.

De Forest went back to his work. Later in 1914 the Telephone Company purchased additional rights to the use

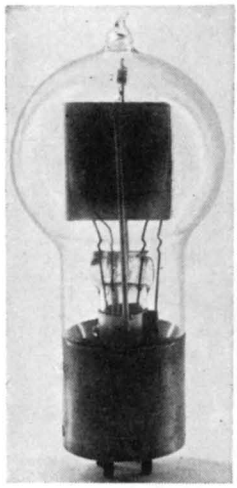

Fig. 138.

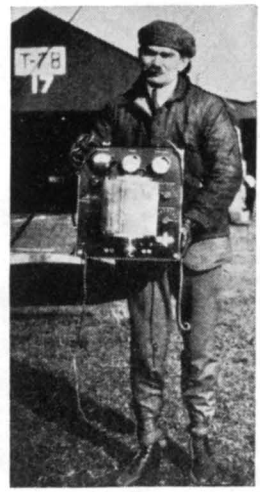

Fig. 139.

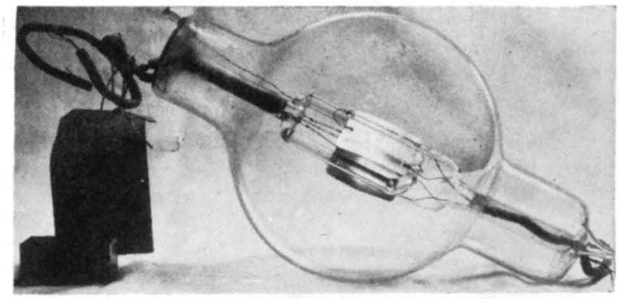

Fig. 140.

of the Audion, this time in the field of radiotelephony, for $90,000. With this additional capital de Forest's work proceeded more rapidly. The High Bridge factory was equipped with newer and better machinery, particularly with the latest and best vacuum pumping equipment. The manufacture of "Oscillions," the name given to Audions intended for use as oscillators, first of the smaller sizes and later of the larger ones, was begun.

One of the smaller types developed was the so-called "Singer" type Audion, which obtained its name from one of its uses—that of producing audio-frequency oscillations, or "singing."

The earliest models of this type had candelabra bases and the grid structure was supported by glass rods. One of the oscillators, denoted as the "Type S Oscillion" incorporating this early model is shown in Fig. 135 and the Oscillion itself is shown in Fig. 136. These Oscillions were used by de Forest in a "musical" instrument, the predecessor of such present-day devices as the Novachord and Solovox.

De Forest demonstrated this musical instrument before the New York Electrical Society in December 1915. While the Proceedings of this Society contain no record of this demonstration, there appeared in one of the popular electrical magazines of that time an article [169] by de Forest on this application of the Audion.

A later variant of the "Singer" type Audion, equipped with the "Shaw Standard" base, and with radically different internal construction is shown in Fig. 137. A rectifier version of this same tube, later used in some of the low-powered de Forest transmitters, appears in Fig. 138.

Other sizes of Oscillions began to come into being. De Forest realized the growing importance of aircraft in

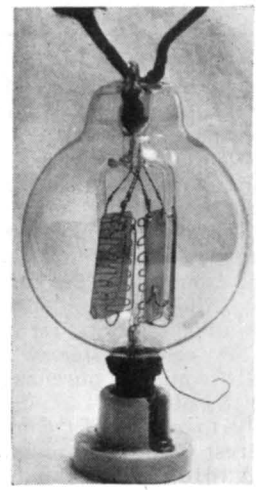

Fig. 141.

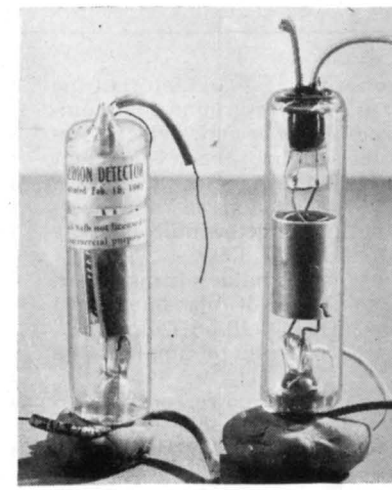

Fig. 142.

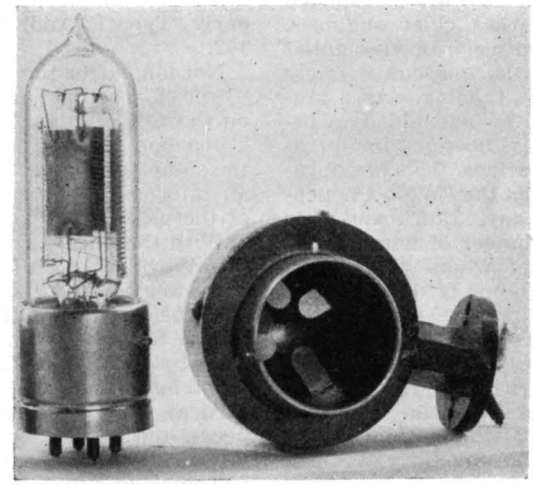

Fig. 143.

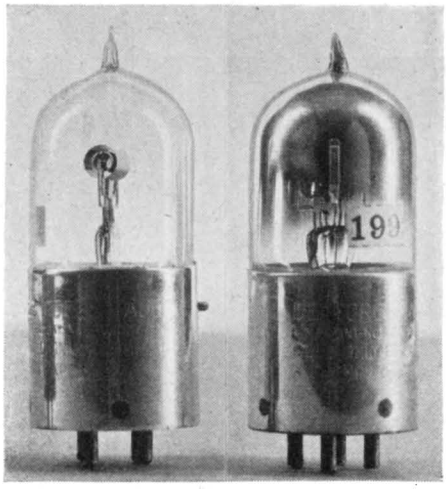

Fig. 144.

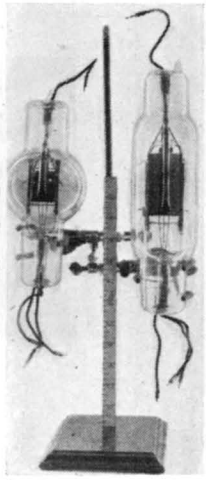

Fig. 145.

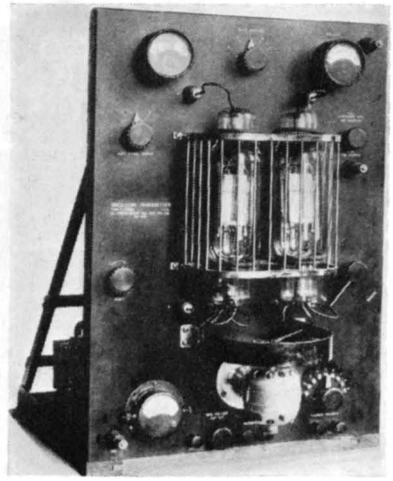

Fig. 146.

the modern way of life and felt that the necessity of plane-to-ground communications would soon become evident. Accordingly, he set about the development of an Oscillion aircraft transmitter. One of the earlier steps in that direction is the transmitter unit held by Dr. de Forest in Fig. 139.

A somewhat similar transmitter, using the same type of tube, but known as the "Type OJ3 Oscillion Telephone," was offered for sale to amateurs in 1917.

Other and higher power output Oscillions followed. This tube (Fig. 140) operated at a plate potential of 1500 volts and had an output of 250 watts. It was this type of tube which was used in the transmitter installed at High Bridge. Through this transmitter the returns of the Presidential election of 1916 were broadcast.

Late in 1915 de Forest engaged Robert F. Gowen as chief engineer. Gowen was not only a trained scientist but an enthusiastic amateur wireless operator of long standing. As a student at Harvard he had aided in organizing a wireless network for intramural communications. This organization was known as the "Weld Phonepterograph Company, Ltd." and was composed of a number of wireless enthusiasts, each of whom operated a wireless station in one of the buildings on the campus.

Under Gowen's supervision High Bridge turned out a number of sizes and types of tubes. In the way of detector tubes there was an improved spherical Audion, which is shown in Fig. 141. This, like the early Western Electric tubes, had a double glass arbor for supporting and stiffening the plate and grid assemblies, but unlike the Western Electric tube had two filaments.

Meantime, competition for the business of the radio amateur began to appear. A cylindrical three-electrode detector tube, known as the "Audio Tron" was put on the market by a West Coast concern. These tubes were good detectors, and what was most important to the amateur—whose ambitions always exceeded his financial resources—could be purchased alone. As will be recalled from a previous article the de Forest Audions could be legitimately obtained only by first buying a complete Detector, after which renewal bulbs could be purchased upon returning the old ones.

Probably to meet such competition the de Forest Company brought out a tubular Audion, designated as the "Type T," which was first offered for sale in April 1916. The "Type T" was a single filament tube, and sold for about the same price as the "Audio Tron," which was a double filament type. A photograph of two of the early "Type T" Audions is given in Fig. 142.

Not long after the appearance of the "Type T" the de Forest Company put on the market the "Type PJ Oscillion Telephone," using an Oscillion of about the same size as the "Type T" but with an internal structure resembling that of the older spherical bulbs.

With the entry of the United States into World War I all amateur activity was stopped, and the de Forest Company began to manufacture tubes for the U. S. Government. One of these, used by the Signal Corps, was designated as the "VT-21." This tube operated at a filament current of 1.1 amperes, and had an amplification factor of 10-12, with plate resistance of 60,000 ohms, at a plate voltage of 20 volts. The bulb shape of the VT-21 varied. De Forest also made tubes for the U. S. Navy, one of these being designated as the "CF-185." This tube was at first supplied to fit the Navy Standard

(*Continued on page* 118)

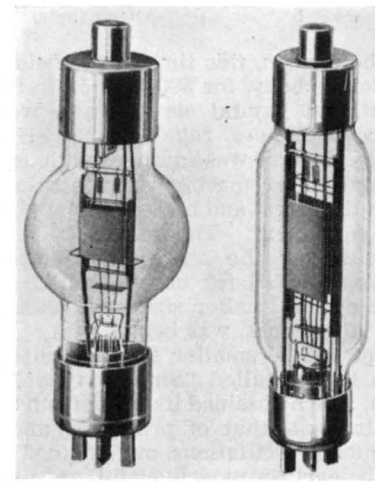

Fig. 147.

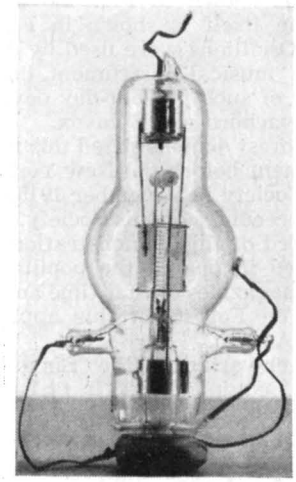

Fig. 148.

the ends of the crossarm. It is effective in providing low angle radiation so desirable in ground to ground communication (as distinguished from ground to airplane communication) at v.h.f. and u.h.f. frequencies.

Horizontal Dipoles and Arrays

Commercial FM and television utilize horizontally polarized waves for most broadcasting functions. Some of the reasons which have been advanced for using this type of polarization are:

1. There is less reflection from buildings in urban areas.
2. There is less interference from man-made noises.
3. Arrays of horizontal dipoles are easier to construct.

A single element horizontal dipole is slightly directive in itself, having maximum radiation in a broadside direction. This directivity may be increased by using a long wave antenna, or a collinear array of dipoles. Parasitic elements tend to concentrate the radiation broadside in one direction.

In addition to directivity in a horizontal plane, maximum vertical radiation at low angle is a most desirable feature for antennas in the v.h.f. and u.h.f. frequency ranges. This effect may be achieved with a broadside array of horizontal dipoles stacked one above one other. In commercial FM and television, uniform radiation in a horizontal direction is often also desirable, so that points in all directions may be served equally well. This uniform horizontal radiation pattern may be produced by crossing two horizontal dipoles perpendicularly at their centers, which combination of dipoles is known as the "turnstile" antenna. A stacked array of "turnstile" antennas will serve two desirable functions, both concentrating the radiation in a horizontal plane and distributing it uniformly in all directions along this plane.

Horizontal dipoles may be mounted directly at right angles to the crossarm. At the lower frequencies, these dipoles, unless made out of rigid tubing, may need auxiliary support in a horizontal plane. Parasite elements may be mounted in a manner similar to the dipoles. Inasmuch as the crossarm may be rotated in any direction, the directivity of such an array may be changed at will. A stacked broadside array may be mounted by using an auxiliary vertical shaft affixed to the crossarm. For "turnstile" arrays, however, as with other special horizontal arrays, it may prove most expedient to dispense with the crossarm and make the mounting an integral part of the array.

-30-

Saga of the Vacuum Tube

(*Continued from page* 54)

three-contact socket, and had a machined fiber base. The grid was of fine tungsten wire wound on a glass frame. The plates were of sheet tungsten. Subsequently, these tubes were made with the later standard four-point base and one of this variety, using a metal base, is shown in Fig. 143. These tubes were also provided with an adapter which enabled them to be used in the candelbra socket which was characteristic of previously made Audions. The "CF-185" tubes were the first to be made by de Forest using oxide-coated filaments and were claimed to have a life of 5000 hours at a filament current of 0.85 ampere.[170]

It will be remembered that when de Forest sold the rights to the Audion to the A. T. & T. Company he retained a personal, non-transferable right to make and sell Audions for radio use. This he continued to do. In 1914 the Marconi Wireless Telegraph Company of America, owners of the United States Patent on the Fleming Valve, instituted suit against de Forest and the de Forest Radio Telephone and Telegraph Company, claiming that the de Forest Audion was an infringement on the Fleming patent. De Forest promptly filed a countersuit claiming infringement of his patents by the Marconi Company. Before the cases came to trial the Marconi Company confessed judgement as to its infringement of the de Forest patent and were enjoined from further infringement. The case against de Forest, which will be discussed in a later article, was tried and the decision of the Circuit Court was filed on September 20, 1916.[171] This decision was later upheld by the Circuit Court of Appeals.[172]

"Oh hello, is that you, Mert?"

The decision held that the Fleming patent had been infringed and an injunction was issued restraining de Forest from further manufacture and sale of Audions for radio use. This produced a stalemate. De Forest could not make Audions because they infringed the Fleming patent. The Marconi Company could not make Audions because that would infringe the de Forest patent. They could make Fleming Valves, but that was not what they wanted.

During World War I de Forest made Audions for the U. S. Government under guarantee of immunity. After the War the Marconi Company sued the U. S. Government because of the infringements, and this suit was decided only last year. The decision of the United States Supreme Court, handed down on June 21, 1943,[173] held that the Fleming patent had not been infringed, and that the patent itself was void, thus, in effect, reversing the decisions rendered back in 1916 by the Circuit Court and confirmed by the Circuit Court of Appeals.

After the war the injunctions again became operative and the stalemate was restored. It was broken early in May, 1919,[174] when representatives of de Forest and Marconi met with a West Coast manufacturer named O. B. Moorhead. Moorhead had been making and selling "Electron Relays" before the war and was ready to engage in the manufacture of tubes. The conference resulted in de Forest joining forces with Moorhead, in order to permit them to use de Forest's personal license to manufacture Audions, and in the Marconi Company's extending their patent rights to the combination for the manufacture and sale of receiving tubes. The Marconi Company was made the distributing agent for the combination. Two distributing companies were organized. The Pacific Radio Supplies Company had the West Coast territory and the Atlantic Radio Supplies Company covered the eastern part of the United States.

The first tubes put out by this combination were the unbased Moorhead Electron Relay and the Moorhead VT Amplifier.[175] This latter was a high-vacuum tube which had been made by Moorhead during the war and sold to the U. S. Navy under the designation "SE-1444."[176]

The unbased Electron Relay was soon abandoned in favor of a based tube[177] which was also called the "Moorhead Electron Relay." The base was the so-called "Shaw Standard"[178] and was used on the SE-1444 and the Moorhead VT Amplifier as well.

The Marconi Company, in advertising the hard tube, designated it as the "Marconi VT." This tube bore the de Forest and Marconi markings on the brass base, in depressed characters, and the Moorhead markings etched on the glass bulb. The life was claimed as 1500 hours.[179] The glass of some of these tubes had a golden tinge, and the tube was familiarly known as the "Golden VT." It operated with a fila-

ment current of 0.7 ampere at about 4 volts.[180]

The tubes made and sold by this organization were the only receiving tubes legally available to the public until the foundation of the Radio Corporation of America.

A short time later the "Electron Relay" was replaced by the "De Forest Type 20" detector. This was at first advertised[181] as a "soft" tube, and is shown at the left in Fig. 144. Later it was apparently made as a hard vacuum tube since the variant at the right in Fig. 144 has a getter.

After World War I de Forest began to develop the higher power Oscillions. This he could do because the injunction applied only to receiving tubes. Two of the postwar Oscillions are shown in Fig. 145. The tube at the left is of 250 watts *input* rating and that at the right is 500 watts *input* rating. Fig. 146 shows a transmitter made by the de Forest Company using two of these "500-watt" tubes. Later models of these tubes are shown in Fig. 147.[182] These later models, as will be seen from the figure, were provided with end fittings to facilitate mounting and connecting into the circuit. They appeared on the market about 1920. In addition to those shown there was also made a 1000-watt *input* tube of similar construction.

With the advent of broadcasting the market for receiving tubes expanded enormously and the demand became huge. The Fleming patent expired in 1922 and its expiration left the de Forest Company free to manufacture Audions for radio use. Some time later the De Forest Radio Telephone and Telegraph Company underwent a reorganization and became the De Forest Radio Company. The new company proceeded to put out a line of vacuum tubes for the broadcast receiving set market.[183] They also made transmitting tubes, one of which, designated as the "Type H" and intended for amateur use, is shown in Fig. 148. This tube was rated at 150 watts *input* and operated at plate voltages from 500 to 3000 volts.[184] There was also a rectifier version of this tube known as the "Type HR."[185]

De Forest's interest in the newly reorganized company was a nominal one, and he began the pursuit of other goals, notably in the sound motion picture field.

The development of the hard vacuum tube occurred almost simultaneously in the laboratories of both the Western Electric Company and the General Electric Company. The work of the Western Electric Company has been covered in previous installments. In our next article we will discuss the evolution of this type of tube in the laboratories of the General Electric Company.

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179. *Marconi Wireless Telegraph Company of America advertisement in Radio Amateur News, Vol.* 1, *No.* 2, *August* 1919, *page* 52.

180. "*The Marconi VT.*" *Wireless Age, August* 1919, *pages* 33-34.

181. *Pacific Radio Supplies Company advertisement in Radio Amateur News, Vol.* 1, *No.* 11, *May* 1920, *page* 606.

182. *Catalog No.* 101, *Lee de Forest, Inc., San Francisco, Cal.*

183. *Radio Broadcast, September* 1923, "*Advertiser Section.*"

184. *De Forest Radio Company advertisement in QST, Vol.* 10, *No.* 8, *August* 1926, *page* 77.

185. *De Forest Radio Company advertisement in QST, Vol.* 10, *No.* 12, *December* 1926, *page* 99.

CAPTIONS FOR ILLUSTRATIONS

Fig. 135. "Type S Oscillion." Reproduced from page 920 of April, 1917 Electrical Experimenter.

Fig. 136. Early "Singer" type Audion with candelbra base. Tube loaned for this photograph by Robert F. Gowen.

Fig. 137. Later version of "Singer" type Audion.

Fig. 138. Front view of rectifier tube of Singer type.

Fig. 139. Early type of Oscillion Aircraft Transmitter, held by Dr. de Forest. Photograph courtesy of Robert F. Gowen.

Fig. 140. High power Oscillion (250 watts), vintage of 1915.

Fig. 141. Improved form of spherical Audion detector, with glass arbors to promote rigidity of elements.

Fig. 142. "Type T" Audions. Left—with paper label. Right—turned to show "DF" stamped on plate.

Fig. 143. "Type CF-185" with four-point base and socket.

Fig. 144. De Forest "Type 20." Left—early type of soft tube. Right—later tube with magnesium flash.

Fig. 145. 250 watt input and 500 watt input Oscillions—front view.

Fig. 146. Oscillion Transmitter "Type OT-200" using 2500 watt input Oscillions. Photograph courtesy Robert F. Gowen.

Fig. 147. 250 watt input and 500 watt input Oscillions—vintage of 1920—with end fittings. Photograph courtesy Robert F. Gowen.

Fig. 148. De Forest "Type H" short wave transmitting tube—vintage of 1926.

(To be continued)