# THE SAGA OF THE VACUUM TUBE

### by GERALD F. J. TYNE

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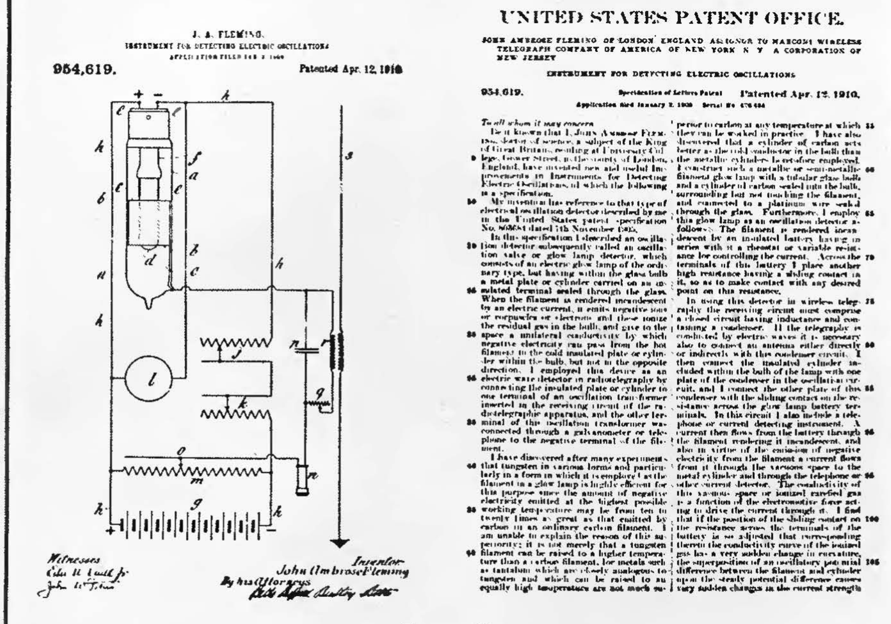
***Part 5. The era of controversy between patent rights on thermionic tubes designed by de Forest, Fleming, Weagant and others.***



UNITED STATES PATENT OFFICE.

JOHN AMBROSE FLEMING OF LONDON ENGLAND ASSIGNOR TO MARCONI WIRELESS TELEGRAPH COMPANY OF AMERICA OF NEW YORK N Y A CORPORATION OF NEW JERSEY

INSTRUMENT FOR DETECTING ELECTRIC OSCILLATIONS

954,619. Specification of Letters Patent Patented Apr. 12, 1910.

Figure 28.

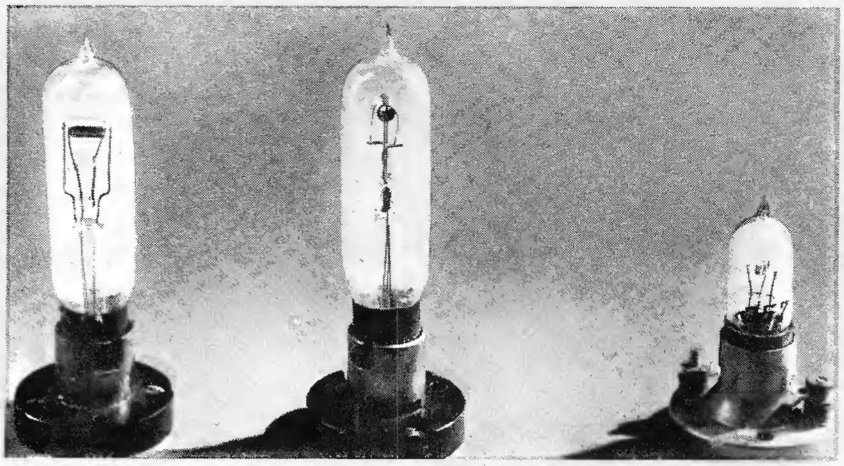


Figure 29.

AFTER the first applications of the valve to the rectification of high frequency oscillations, Fleming began to study their characteristics in detail. Some of the valves had filaments of tungsten. He determined the characteristics of the valves with varying plate potential, this plate potential being supplied by a separate battery which had its negative terminal connected to the negative terminal of the filament. He found that the curves were different with different filaments and different degrees of vacua. Analysis of the curves so obtained suggested to him another means of using the valve as a detector. If the plate potential could be adjusted to cause the valve to operate on the bottom bend of this characteristic, then the superimposed signal oscillation would produce a large change in the mean current through the vacuous space. This would mean an increase in the sensitiveness of the device as a detector.

Fleming applied on June 25, 1908, for a British patent on the use of an oscillation valve with a tungsten filament, and showed such a valve with the filament operated from a high voltage battery, using a large series resistance, and the plate potential adjustable by means of a potentiometer to obtain operation on the bend in the characteristic. The complete specification of this patent was accepted on April 15, 1909 and a corresponding United States patent was obtained in 1910.[112] (See Figure 28.)

This same bend in the characteristic had been shown by Fleming in his February, 1905, paper before the Royal Society, but no application of this phenomena was mentioned until the application for the above-mentioned British patent was filed. It is interesting to note that this application is equivalent to that described in de Forest's paper on the two-electrode Audion published in October, 1906, a year and a half before. The difference between them lay in the fact that de Forest used a separate battery to supply the plate potential, whereas Fleming obtained the corresponding potentials by means of a potentiometer arrangement on the higher voltage filament battery.

Somewhat later, in a paper[113] by Dr. R. S. Willows and Mr. S. E. Hill, there were described experimental Fleming valves in which a Wehnelt oxide-coated cathode was used. Trouble was experienced in these valves with loss of coating from the heating wires. It is not known to the author whether or not any such tubes were ever used commercially.

In the court contest in the United States over the Fleming valve and the de Forest Audion, the attorneys for the Marconi Wireless Telegraph Company of America (the assignees of Fleming's U.S. patents) found it necessary, in order to make the patent stick, to disavow certain of the rectifier claims made in the original specification which were not limited to high frequency applications.

This was necessary because in the use of a thermionic device as a rectifier, the Fleming utilization was anticipated by the Wehnelt valve. Within these limitations the Fleming utilization patent for wireless detection was basic. In a practical sense it contributed little, if anything, to wireless telegraphy of that time. It was less sensitive than other known forms of detector, such as the electrolytic and crystal types, and never came into general use. What usefulness it might have had was soon overshadowed by the development of an electronic device of increased sensitiveness, the de Forest Audion, the first practical three electrode thermionic tube, which will be treated at length subsequently.

The Fleming valve enjoyed a brief revival during the early days of broadcasting in the United States, after the expiration of the Fleming patent. A number of types of diode were put on the market in this country at that time. Examples of these tubes are the "Dietzen Vacuum Tube,"[114] the "Electrad Diode,"[115] and the "Margo Detector,"[116] the latter two of which are shown in Figure 29. They had a rather short vogue, since they could neither regenerate nor amplify.

The development of the de Forest Audion led to a long and bitter controversy between Fleming and de Forest, and finally resulted in the famous Marconi-de Forest patent suit, of which more later.

While this suit was still unsettled the American Marconi Company, probably motivated by a desire to have available an alternative device in case the decision in the suit was unfavorable to them, began the development of a new tube. This work was done under the guidance of the late Roy A. Weagant, who was at that time chief engineer of the Marconi Wireless Telegraph Company of America. Weagant used a Fleming valve type tube and endeavored to obtain control of the electron stream by means of a third electrode which was placed outside of

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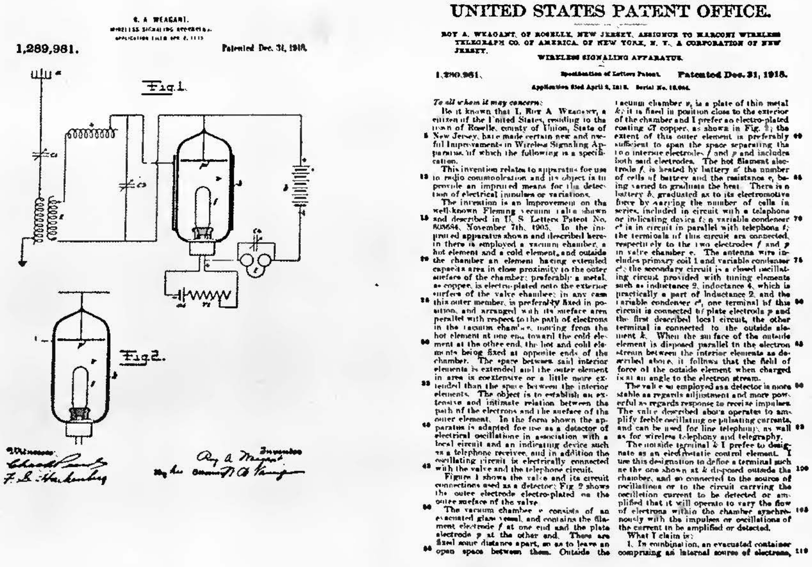

UNITED STATES PATENT OFFICE.

ROY A. WEAGANT, OF ROSELLE, NEW JERSEY, ASSIGNOR TO MARCONI WIRELESS TELEGRAPH CO. OF AMERICA, OF NEW YORK, N. Y., A CORPORATION OF NEW JERSEY.

WIRELESS SIGNALING APPARATUS.

1,289,981. Specification of Letters Patent. Patented Dec. 31, 1918.

Application filed April 8, 1915. Serial No. 18,044.

*To all whom it may concern:*

Be it known that I, Roy A. Weagant, a citizen of the United States, residing in the town of Roselle, county of Union, State of New Jersey, have made certain new and useful Improvements in Wireless Signaling Apparatus, of which the following is a specification.

This invention relates to apparatus for use in radio communication and its object is to provide an improved means for the detection of electrical impulses or variations.

The invention is an improvement on the well-known Fleming vacuum valve shown and described in U. S. Letters Patent No. 803684, November 7th, 1905. In the improved apparatus shown and described herein there is employed a vacuum chamber, a hot element and a cold element, and outside the chamber an element having extended capacity area in close proximity to the outer surface of the chamber; preferably a metal, as copper, is electro-plated onto the exterior surface of the valve chamber; in any case this outer member, is preferably fixed in position, and arranged with its surface area parallel with respect to the path of electrons in the vacuum chamber, moving from the hot element at one end toward the cold element at the other end, the hot and cold elements being fixed at opposite ends of the chamber. The space between said interior elements is extended and the outer element in area is coextensive or a little more extended than the space between the interior elements. The object is to establish an extensive and intimate relation between the path of the electrons and the surface of the outer element. In the form shown the apparatus is adapted for use as a detector of electrical oscillations in association with a local circuit and an indicating device such as a telephone receiver, and in addition the oscillating circuit is electrically connected with the valve and the telephone circuit.

Figure 1 shows the valve and its circuit connections used as a detector; Fig. 2 shows the outer electrode electro-plated on the outer surface of the valve.

The vacuum chamber *e* consists of an evacuated glass vessel, and contains the filament electrode *f* at one end and the plate electrode *p* at the other end. These are fixed some distance apart, so as to leave an open space between them. Outside the vacuum chamber *e*, is a plate of thin metal *k*; it is fixed in position close to the exterior of the chamber and I prefer an electro-plated coating of copper, as shown in Fig. 2; the extent of this outer element is preferably sufficient to span the space separating the two interior electrodes *f* and *p* and includes both said electrodes. The hot filament electrode *f*, is heated by battery *a*, the number of cells of battery and the resistance *c*, being varied to graduate the heat. There is a battery *b*, graduated as to its electromotive force by varying the number of cells in series, included in circuit with a telephone or indicating device *t*; a variable condenser $c^3$ is in circuit in parallel with telephone *t*; the terminals of this circuit are connected, respectively to the two electrodes *f* and *p* in valve chamber *e*. The antenna wire includes primary coil 1 and variable condenser $c^2$; the secondary circuit is a closed oscillating circuit provided with tuning elements such as inductance 2, inductance 4, which is practically a part of inductance 2, and the variable condenser $c^1$, one terminal of this circuit is connected to plate electrode *p* and the first described local circuit, the other terminal is connected to the outside element *k*. When the surface of the outside element is disposed parallel to the electron stream between the interior elements as described above, it follows that the field of force of the outside element when charged is at an angle to the electron stream.

The valve so employed as a detector is more stable as regards adjustment and more powerful as regards response to receive impulses. The valve described above operates to amplify feeble oscillating or pulsating currents, and can be used for line telephony as well as for wireless telephony and telegraphy.

The outside terminal *k* I prefer to designate as an electrostatic control element. I use this designation to define a terminal such as the one shown at *k* disposed outside the chamber, and so connected to the source of oscillations or to the circuit carrying the oscillation current to be detected or amplified that it will operate to vary the flow of electrons within the chamber synchronously with the impulses or oscillations of the current to be amplified or detected.

What I claim is:

1. In combination, an evacuated container comprising an internal source of electrons,

**Figure 30.**

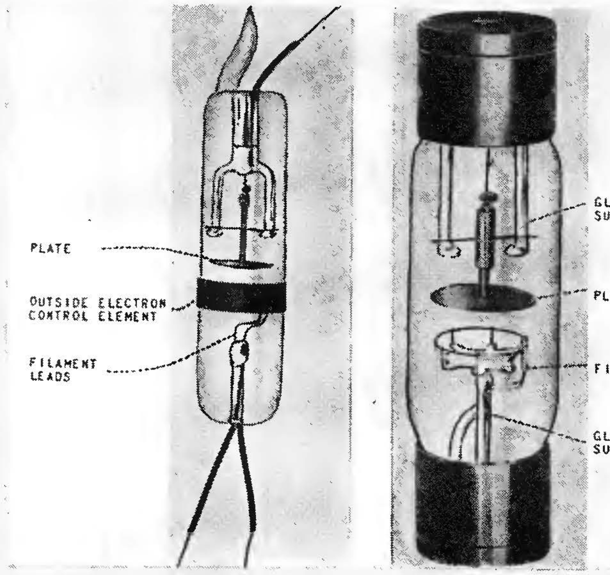

**Figure 31.**

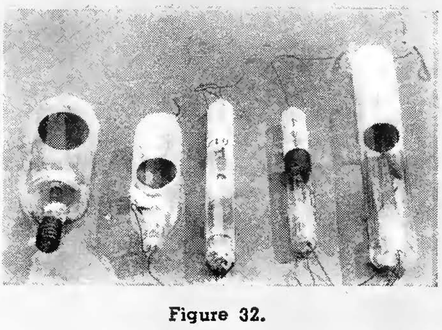

**Figure 32.**

**Figure 33.**

which separates the leafy portions from the woody stem and crushes the sappy parts, the electric eye being the expert grader. This dehydrator would combine several functions into one operation. It would feed green fodder or other material intended for livestock onto an endless belt, cut the plants into suitable lengths, separate, electronically, the leafy portions from the sappy stems, crush the stalks, pick up the layer of drying material, turn it upside down and deposit it loosely along the traveling conveyor. Soybeans, alfalfa or clover are loaded onto this slowly moving conveyer belt. After passing through crushing rollers which pulverize the sappy stems to a more rapidly drying status, they are then carried through a heating chamber where moisture is expelled. During the process of drying, the temperature is adjusted correctly, thus avoiding scorching or burning the material, a common complaint with some driers. There are a succession of heat zones each supplied with low humidity air, heated to exactly the right temperature, to attain the maximum evaporative effect for each stage of the dehydrating process. The drying is conducted, in part, in an oxygen-free atmosphere and in a chamber wherein all products of combustion are burned completely without smoke.

The units of this community dehydrator consist of a supporting framework; a continuous belt of two flexible steel bands mounted on the framework; a main boxlike structure, extending the length of the conveyer belt and forming an airtight housing for the conveyer screen; another chamber which has a metallic tube and an oil burner for heating the material to be dehydrated; electronic tubes; and other equipment. The interior of the drying chamber has eight cross openings with an air intake opening controlled by a door. This series of hot-air discharge chambers provides an accurate control over the amount of hot gas admitted to chambers.

The above mentioned examples of various applications of radionics to modern farming, serve to show to a certain extent what progress has been made and something of what may be expected in the future. No article of this nature would be complete without mentioning the future possibilities of maintenance and repair in this field. The many radionic devices, which are now available, and those which will be available in the future, will require the services of a great many trained technicians. Men presently engaged in radio servicing, or kindred maintenance, will find this a profitable and timely field to enter. The servicing of the devices should do much to build a splendid post war business for these men, particularly in rural areas.

It is important that the serviceman bring his knowledge up to date on these new devices in order that he can take full advantage of these new opportunities.

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## Saga of Vacuum Tube

(*Continued from page 27*)

the tube, and hence might not be considered to be within the scope of the de Forest patents. On December 31, 1918, U.S. Patent No. 1,289,981 was issued to Weagant on a tube of this type.[117] (See Figure 30.) The Weagant Valve, as the device was called, was never applied commercially to any great extent, probably because the decision in the Marconi-de Forest suit was favorable to the Marconi Company. Figures 31, 32, and 33 show various forms of the Weagant Valve, that of Figure 33 being a proposed commercial form of the device. The circuits to be used with this valve were similar to those used with the conventional three-electrode tube, and were published in a magazine article about the time the patent was issued.[118]

With the development of the multi-electrode tubes of the late 1920s and early 1930s communications engineers had available a method of obtaining substantial amplifications at radio frequencies. This resulted in a second revival of the diode for use as a detector. When the signal input to the detector can be made of the proper value, this type of detection presents certain advantages in the way of freedom from distortion. Hence many modern radio receivers use such detectors. A typical detector tube of this sort is the RCA 6H6, which is a double diode detector. Study of Figure 34 will clearly show the changes which differentiate this modern diode from its progenitor, the Fleming valve. These advances are in the nature of engineering refinements, the principle of operation is still the same. The output, however, is utilized not only

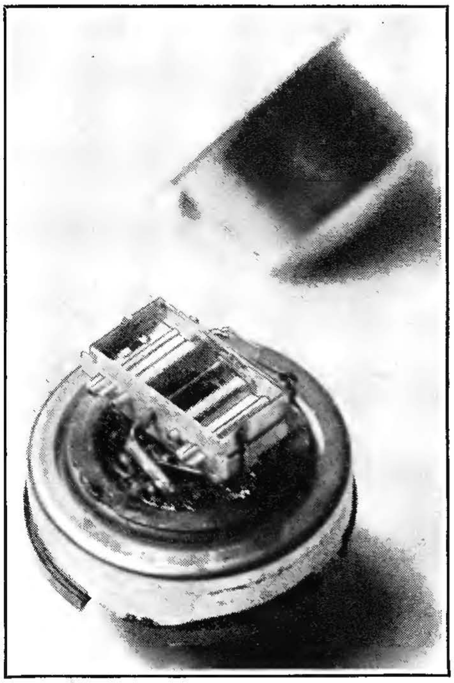


Figure 34.

to provide the audio waveform which was superimposed on the carrier at the transmitter, but also to provide energy for other purposes, such as automatic adjustment of the gain of the preceding radio frequency amplifier. This provides an audio frequency output which is reasonably constant and independent of the variations in the received signal over the operating range of the circuit.

There is still another use of the diode on which we have not yet touched. This is in the field of power frequency rectification. In the early wireless receivers, even well into the broadcast era, dry cells or small storage batteries were used as a source of plate potential. Their use had its disadvantages. The cost was high for the energy which they furnished. The plate potential always existed, even though the set was not in operation, and might be dangerous. If heavy duty batteries were used, in an attempt to reduce the cost per energy unit, the space required for them might be as great as for all the rest of the receiving equipment. These disadvantages became more important with the trend to the higher voltages required for the power output tubes needed for satisfactory loud-speaker operation.

In the case of tube transmitters, the plate potential was at first supplied by generators. High voltage d.c. generators are difficult and expensive to build and, like all rotating machinery, require expert maintenance. A static source of power for the transmitting tubes was much to be preferred, hence the power rectifier was developed.

The first power frequency rectifier of the thermionic type was due to Dr. Arthur Wehnelt of the University of Erlangen, the inventor of the Wehnelt, or oxide-coated, cathode.

In 1903 Wehnelt published a paper[119] describing a method of obtaining "negative ions" in great quantities from incandescent metallic compounds. He used a platinum wire, or platinum strip, coated with calcium or barium oxide, as the cathode in a discharge tube and found that there was a strong emission of negative ions from the cathode when it was made incandescent. He further described experiments which he made on these phenomena in other papers in 1903[120] and 1904.[121]

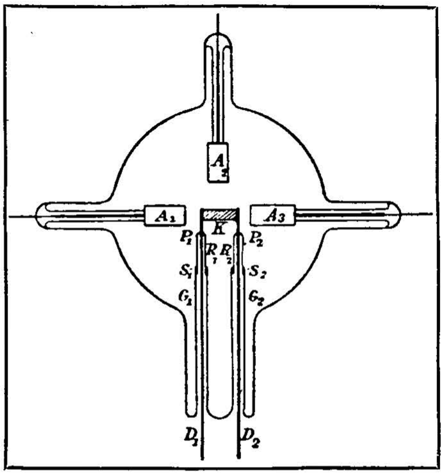
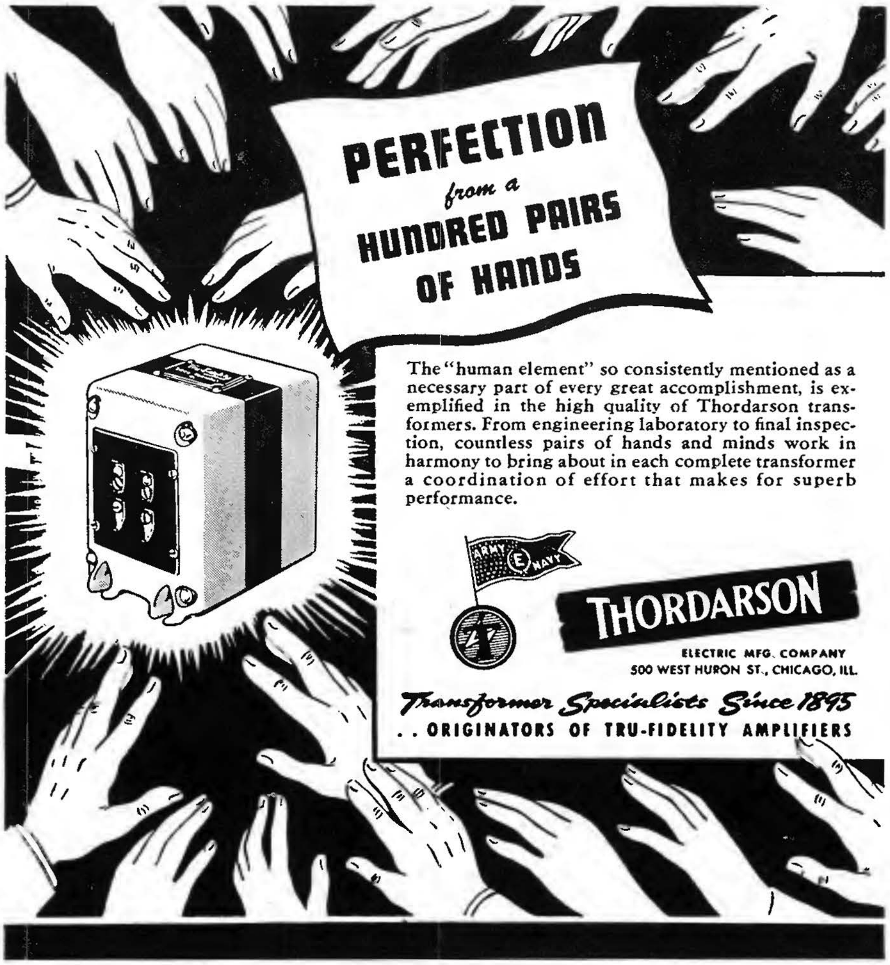


Fig. 35.

On January 15, 1904, he applied for a German patent[122] for the use of such a discharge tube, containing a heated cathode with these metallic oxides, as a rectifier for transforming single phase and polyphase alternating currents into direct currents. No mention was made of any application to high frequency oscillations or wireless telegraph use.

In 1905 he described the use of this device in an article[123] entitled "An Electric Valve Tube" and suggested its use for charging storage batteries, and for supplying potential for the direct operation of Roentgen tubes. This paper was a short summary and was followed by a more complete exposition in 1906.[124] In this last paper he showed that this valve-tube could also be used as a rectifier of high frequency currents. However, it should be noted that this was subsequent to the papers published by Fleming on the use of his valve as a rectifier of high frequency oscillations, and in fact Wehnelt refers to Fleming's work in a footnote in his article. The tube as constructed by Wehnelt is shown in Figure 35.

There appears to have been little



done in this phase of diode development for a number of years thereafter, until the necessity arose for obtaining very high direct current potentials for x-ray work. The initiative in the subsequent development work along this line appears to have been taken by the General Electric Company, whose work will be described in a subsequent article.

## References

113. *Willows, Dr. R. S. and Hill, S. E.: "Vacuum Oscillation Detectors." Electrician, Vol.* 48, *No.* 8, *December* 1, 1911, *pp.* 302-303.

114. *Dietzen Vacuum Tube: See advertisement in Radio News, Vol.* 5, *No.* 5, *November* 1923, *p.* 659.

115. *Electrad Diode: See advertisement in Popular Radio, May* 1923, *p.* 22.

116. *Margo Detector: See advertisement in Radio News, Vol.* 5, *No.* 2, *August* 1923, *p.* 206.

117. *Weagant, Roy A.: U. S. Patent No.* 1,289,981, *application date April* 2, 1915, *issued December* 31, 1918.

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121. *Wehnelt, Arthur: "Uber den Austritt negativer Ionen aus gluhenden Metallverbindungen und damit zusammen hangende Erscheinungen." Annalen der Physik, Vol.* 14, 1904, *pp.* 425-468. *See also Physikalische Zeitschrift, Vol.* 5, *No.* 31, 1904.

122. *Wehnelt, Arthur: German Patent No.* 157,845, *Klasse* 21*g, application filed January* 15, 1904, *issued January* 13, 1905.

123. *Wehnelt, Arthur: Sitzungber. der Physik-Medic. Soc. zu Erlangen, Vol.* 37, 1905, *pp.* 264-269. *This is an abstract of the paper referred to in reference* 124.

124. *Wehnelt, Arthur: "Ein Electrische Ventilrohr." Annalen der Physik, Vol.* 19, 1906, *pp.* 138-156.

## Figure Captions

Figure 28. Fleming's Later United States Patent, showing use of biasing potential on plate.

Figure 29. Left and Center, Electrad Diode. Right—Margo Detector.

Figure 30. Weagant Valve Patent.

Figure 31. Left—Weagant Valve with outside electrostatic control element in position. Right—Weagant Valve with control element removed. Photograph Courtesy *Radio Corporation of America.*

Figure 32. Group of experimental Weagant Valves.

Figure 33. Proposed Commercial Form of Weagant Valve.

Figure 34. Modern Diode. RCA 6H6 with cover removed. Photograph Courtesy *Radio Corporation of America.*

Figure 35. Wehnelt Rectifier for Three Phase Operation. Reproduced from *Annalen der Physik—1906.*

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