
# The Vacuum Detector and How It Works

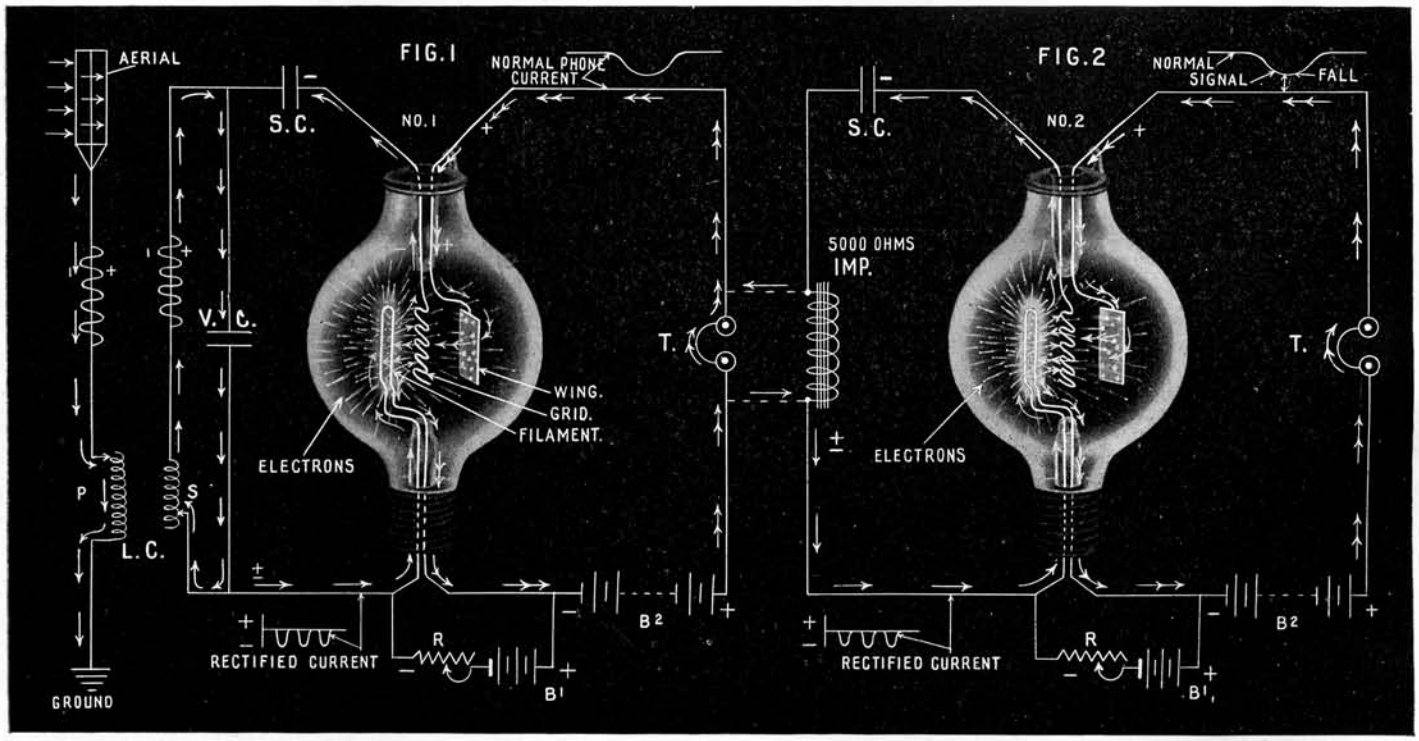
*In endeavoring to make this article an authoritative one, the original manuscript was submitted to Dr. de Forest, Professor J. H. Morecroft, as well as Mr. E. H. Armstrong, who are unquestionably the highest living authorities on this most interesting device. The editors here desire to voice their appreciation to the three distinguished scientists.*

IN the accompanying illustrations we have attempted to show in a graphical manner the general phenomena occurring in the vacuum radio detector of the Audion type, as developed and improved upon by de Forest, Langmuir, Logwood, Armstrong and others. Considering first the basic actions taking place within such a bulb, it may be said that when the lamp filament in the bulb is lighted there takes place a more or less powerful emission of electrons or negative charges of electricity. These electrons are shot off from the filament at low velocity and pass through the wire grid, impinging against the metal wing or plate, as is evident from the illustration.

As pointed out many years ago, particularly in the works of Dr. J. A. Fleming, who first used the Edison lamp rectifier as a radio detector, there is manifested within the bulb, under working conditions, what is known as *unilateral conductivity*. This action concerns the transfer of negative electrical charges from the hot filament to the cold grid or wing. In other words, negative electricity will pass from the incandescent light filament to the wing or grid, *but not in the opposite direction.*

When the evacuated space between the filament and wing is surcharged by the passage of electrons through it, it becomes conductive to the current from the high voltage battery, $B^2$, which flows through the telephone receivers, T. When the filament is lighted, under normal conditions and with no radio signals coming in, there is a steady flow of current through the 'phones and along the wire connected to the wing within the bulb. This current is conducted across the space between the wing and the filament by the ionized state of the gas as aforementioned. This circuit completes itself through the filament feed wire and thence back to the negative pole of the battery, $B^2$.

To start with, suppose that an incoming signal in the form of an electromagnetic wave impinges upon the aerial; this, in turn, sets up high frequency oscillating (or alternating) currents in the antenna circuit, which includes the primary, P, of a loose coupler or transformer, LC. By magnetic induction this current is transferred (and usually changed in potential) to the secondary circuit, S, of the loose coupler. In the circuit at Fig. 1, which is a standard one, an oscillating current will flow around the circuit S-VC. Also this circuit may be tuned to resonance with respect to the incoming wave length. This current, when led off to the filament and grid of the vacuum valve, becomes rectified; that is, the negative pulses are permitted to pass from the hot filament to the cold grid. The grid, too, in virtue of its position in the electron stream, gathers up an appreciable negative charge; in other words, a negative charge is accumulated on it. This charge naturally passes along the wire connected to the right-hand plate of the stopping condenser SC. When this occurs there is a scattering effect in the electron field between the filament and wing, which weakens it, in so far as conductivity is concerned. Hence the current, passing from the positively charged wing to the filament, is reduced, as shown by the graphic curve in the upper right corner of Fig. 1. The time period of this depression in the wing current corresponds to that of a group of sparks, or in other words the *group frequency* of the transmitting station. In consequence the telephone receivers, T, will sound, or their diaphragms are partially released while this effect occurs. On the cessation of the incoming signal, the negative charge on the grid and in the condenser gradually dissipates and the circuits regain their normal state.




**Actions Taking Place in the Vacuum Detector (at Left) and Compound Action of Two Stage Amplifier Comprising Two Bulbs Connected in Cascade.**

It has been found from careful tests conducted at the Radio Laboratory at Columbia University, New York City, in some worthy qualitative experiments made by Professor J. H. Morecroft and Mr. E. H. Armstrong, E.E., that if a *positive* potential is applied to the grid within the detector, that the current passing from the wing itself to the filament will be *increased;* also that with the application of a *negative* potential to the

(*Continued on page 288*)

## THE VACUUM DETECTOR AND HOW IT WORKS.

(*Continued from page 250*)

grid, the wing current will always be *reduced* momentarily, or as long as the potential is applied.

Mr. Armstrong accounts for this action as follows:

An incoming wave train sets up oscillations in the closed circuit S-VC. These are then rectified by the valve action of the hot filament and the cold grid within the evacuated bulb, and the rectified current is used to charge the condenser, SC, in the manner previously explained. The electrons (negative electric charges) emitted by the hot filament readily pass into the wire grid, mounted between the filament and wing, but cannot easily escape. In consequence a negative charge is built up on the side of the condenser, SC, which is connected to the grid. The negative charge thus imparted to the grid scatters the stream of electrons between the filament and wing, which, in turn, means a lower conductivity for this path between the two electrodes. The result is that the wing and telephone current are reduced.

At the end of a wave train the charge in the condenser, SC, gradually leaks off and the wing current returns to its normal value. Thus the condenser charges and discharges as each wave train arrives.

Dr. Bergen Davis of Columbia University points out, however, that the fundamental detecting action is not that of a valve, because the high frequency incoming oscillations cannot be rectified between the filament and grid, particularly as the small condenser in the grid circuit makes true "rectification" impossible, except for the exceedingly brief period while this condenser is being charged. True rectification obviously requires that a D.C. instrument in the circuit shall show a deflection, indicating a rectified or pulsating current, which is entirely absent in the grid circuit. Moreover, it has been proven by Dr. de Forest that if the grid itself is incandescent the detector action is unaffected. The grid, however, does exert a relay or trigger action on the wing current and reduces it by a disproportionately great degree.

Off-hand it may not seem to the uninitiated that any particular advantage accrues with this instrument, but it should be remembered that when the grid effect takes place at each signal, the corresponding amount of current controlled secondarily, and flowing through the high voltage 'phone circuit, T-$B_2$, etc., is many times that flowing in the filament-grid circuit.

Considering Fig. 2 in conjunction with Fig. 1, we have a common form of audion amplifier, of the two-stage type. This circuit yields remarkable amplifying effects. With such a circuit the pulsating current in the 'phone circuit of valve No. 1, passes through a high resistance iron-core impedance, IMP. When this pulsating current passes through the impedance coil there is a tendency for it to be converted into an alternating current, owing to the lagging effect of the iron core. However, the current flowing in the filament-grid circuit of Audion No. 2 is amplified in the same manner as described for Audion No. 1, and amplified charges pass from the filament of Audion No. 2 to the grid. Thus the grid becomes alternately negatively and positively charged and likewise the condenser plate to which it is connected. This Audion then works in the same manner as Audion No. 1, so as to greatly increase the fluctuations in the telephone receiver current from battery $B_3$. In other words it will readily be seen that a very strong amplifying effect takes place in the two detectors, as the current passing through the impedance coil in the secondary circuit of the first bulb is very strong. This comparatively strong current is then used as a *trigger* or control current for Audion No. 2. Since this current in question is many times stronger than the *trigger* current, as in the case of Audion No. 1, it is evident that an extraordinary current change will occur in the 'phone circuit of Audion No. 2.

## MODERN RADIO RECEIVING APPARATUS.

(*Continued from page 252*)

lated by means of a six-point switch, just above the condenser. The filament battery switch is located in the upper left hand corner. This method of generating the undamped oscillations is the most flexible one yet devised and permits a rapid change of frequency, which is very steady and constant.

There is still another method of exciting the receiving apparatus with sustained oscillations, viz., by employing a high frequency buzzer. However, the other methods described are better for commercial work.

The inductive coupler was for many years an inefficient instrument in the radio receiver, due principally to improper design on the part of the radio engineer. As the art advanced the design and working qualities of some of the commercial type of couplers also improved. In Fig. 6 the latest type of loose coupled tuner is illustrated. It is one of the best ever designed as it embodies several important and unique improvements over the older ones.

The primary coil is of pancake form and so constructed that the windings offer the least possible distributed capacity. The value of its inductance is varied by a multi-point switch. The complete unit is supported on two circular rods, which allow it to be moved in or away from the stationary secondary coil. This is radically different from the old types employing a movable secondary coil, and stationary primary. The secondary is made in a similar manner to the primary. Its inductance is also controlled by a multi-point switch, located at the right of the cabinet.

A loading coil is provided inside of the cabinet for higher wave lengths, being controlled by a rotary knob on the top of the instrument. Binding posts are provided for connecting the coupler to the auxiliary necessary apparatus. A very unique but still important feature of this tuner is that when tuning the primary inductance, the coupling primary and secondary are varied at the same time. This saves time on the part of the operator in performing two functions which can be done with one operation.

This article and the one previously published, describing *Modern Radio Transmitting Apparatus,* will undoubtedly prove of benefit to those who are following up the commercial end of radio telegraphy. *Photos courtesy of National Electric Signaling Company.*

## RADIO LINES DOWN.

It will never do for radio telegraph companies to notify the public that business will be accepted subject to delay because "the wires are down," yet such an event happened during the late, or rather the latest, storm at Sayville, L.I., when the antenna of the station at that point was brought down to earth by the weight of sleet.

The time may come when the wireless companies will have to maintain a squad of aeroplane linemen, whose duty it shall be to look for kinks in the air. What?