The Development of the Vacuum Tube

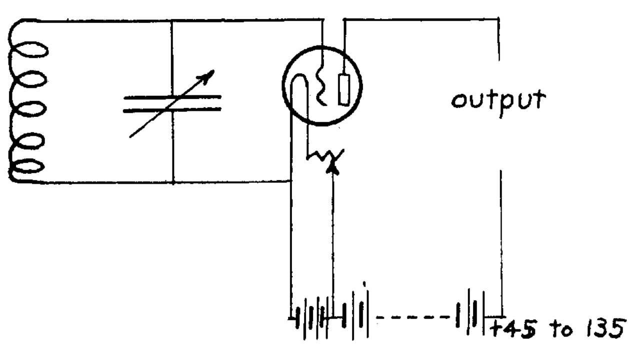
By RICHARD B. JEFFREY, '31

The history of the vacuum tube began with the discovery of the Edison Effect. This, like a great many other important discoveries, was an accident. Edison, while experimenting with his incandescent lamps, had placed more than one filament in the same bulb, and he noticed that if one of the filaments was held positive with respect to the other a current would flow through the bulb. He also found that this positive element, or, as it is now called, plate, did not have to be hot to sustain this current flow. This phenomenon was known for some time as a curiosity, but nothing more. Then Fleming, an English experimenter, noticed that if an alternating current were applied to this plate the current would flow only when the plate was positive. In other words, the tube acted as a rectifier, allowing the current to flow in only one direction. This tube that Fleming made was called the "Fleming Valve" and was the forerunner of all our present day multiple element tubes. In fact, in England a vacuum tube is still called a "valve."

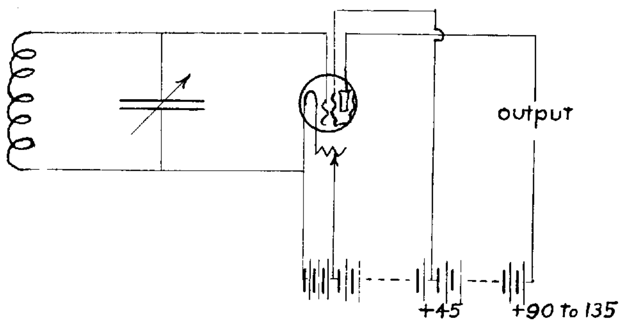
It was not long until this Fleming valve was being used commercially as a rectifier to transform alternating current to direct, and various improvements were added to it until the modern rectifier tubes were evolved. Among the most important improvements were the substitution of a metalic filament for the carbon one, and the introduction of certain gasses into the vacuum to increase the conductivity of the tube.

These diodes or two-element tubes are mentioned because no account of vacuum tube development would be complete without them, but this paper is more concerned with the more complicated tubes used first in telephony and now forming the very heart of radio communication. These were, until very recently, all triodes, or three-element tubes, but lately a tetrode has been introduced, of which more will be said later.

The first application of vacuum tubes to radio, or "wireless" as it was then called, was in the detection of signals. When Marconi invented his wireless he used at first a "coherer," a glass tube filled with metal filings, to detect the signals. This acted like a relay, and the current to work the telephones came from a local battery. Then it was found possible to do away with this complicated system by making use of the rectifying properties of a crystal, notably galena. When signals were received in this way it was the signal current itself that energified the telephones. From this it was only a lgical step to the utilization of the Fleming valve in place of the crystal. It was a more efficient rectifier.



Fundamental triode circuit.



The screen-grid tube (tetrode).

Then Lee DeForest began experimenting and he introduced the third element, the grid. If the vacuum tube is the heart of the radio industry, the grid is the heart of the vacuum tube. It is the valve that controls the action of the tube. DeForest found that if the signal was introduced between the grid and the filament, and the filament and plate were energized by the proper batteries, then the signal obtained between the plate and the filament would be several times input to the grid. It was here that the amplifying action of the tube appeared. For many years the vacuum tube was used in radio solely as a detector, and its development as an amplifier was left to the telephone companies.

With the popularization of the telephone and its increasing use for long distance calls the drop in the line became very troublesome. It was difficult to overcome this trouble, but the invention of the vacuum tube showed the way out. Its amplifying property was made use of and developed by the telephone engineers nad then this improved tube was again applied to radio.

Here the development of the vacuum tube seemed to stop. For years there was really only one type of tube. It was made in different models for different battery voltages, but that was about the only difference between the models. During this period the methods of operating and the circuits were greatly improved, but so much attention was paid to this end of the problem that tubes were forgotten. Then the tide began to turn, until now circuits are forgotten in the rush of new tubes.

The first improvement to come was the thoriated filament, closely followed by the high vacuum. It was found that by covering the ordinary tungsten filament with a coating of thorium oxide the efficiency could be greatly increased and the current consumption lowered. That is why modern tubes do not light up as brightly as an electric light bulb. This coating of thorium oxide makes it unnecessary to heat them so hot, and thus increases the life of the tube. The high vacuum came as the result of the invention of better pumps for evacuating the tubes. The pumps most generally used now use mercury and operate in a manner very similar to that of the small suction pumps used in a chemistry laboratory which are attached to the water pipes. In addition to using these high power pumps, they introduce into each tube certain substances which combine with any air which may be left in the tube. The high vacuum makes a tube quieter in operation and allows the use of higher plate voltages. A high vacuum tube is spoken of as a "hard" tube and makes a better amplifier than a "soft" one.

About 1925 the special purpose tubes began to make their appearance. Before this all tubes had been about alike, and one kind was used throughout a set. This was not a very good arrangement, for a tube that is designed for a detector will not make a good amplifier, and one designed for high amplification will not make a good output tube, and so on. Obviously it was not possible to design one model that could be used everywhere. So the special purpose tubes began to appear. Their characteristics are too complicated to be dealt with here; they make their appearance in the form of special detectors, output tubes, high mu tubes, (mu is a symbol for amplification), radio frequency tubes, and in many other forms.

And now comes one of the two truly great changes in the vacuum tube, the A. C. tube. Since the invention of the first audion, men have dreamed of operating receivers direct from the power mains, but the great obstacle was the difficulty in eliminating the hum. With the introduction of the so called "B battery eliminator" a few years ago, part of this dream was realized, but the filament heating presented a greater problem. Several methods for heating the filaments from the power mains were introduced, but were, in general, unsuccessful. Some of these systems merely reduced the size of the battery required, while the others that eliminated it entirely left much to be desired in the way of quiet operation. A little over a year ago a tube appeared which appeared to be the solution of the problem, but it was not well made and was unreliable. Other manufacturers have conducted research along the same tine, and now the result appears in the form of several efficient and highly reliable A. C. tubes. They differ from most tubes in that they have four elements. The filament, whose duty is to throw out electrons toward the plate, is replaced by a thin piece of metal which has no current flowing through it. To make any common metal throw out these electrons it must be heated to a high temperature. This is accomplished in the ordinary tube by passing a current through the filament, but if this current is alternating, a hum results. In the A. C. tube, however, no current flows through the "cathode," (the metal taking the place of the filament), and it is heated by means of a separate "heater." This heater is just like the "insides" of an electric curling iron or flat-iron, only smaller. In this way the tube is made to operate just like any other tube, but it may be operated directly from the power mains, and thus all batteries are eliminated.

Late in 1927 a tube was introduced to this country which may truly be called the greatest single step in the development of radio since Hertz's first experiments. This was the screen-grid tube. It is almost safe to predict that it will bring the most revolutionary changes radio has ever known. The operation of this tube cannot be explained completely without a rather technical discussion. The great obstacle to high amplification with ordinary tubes has been the difficulty in controlling oscillation, which results in squeals. It is caused mainly by the short distance between the plate and grid. In the screen-grid tube the plate is entirely surrounded by a second grid, called the screen-grid. This is connected to the battery that supplies the plate. The effect of this screen-grid being between the plate and the control grid is the same as if the plate and control grid were several feet apart. The oscillation from thsi source is almost entirely stopped. This results in much higher effiicency. It is interesting to compare the results obtained with this tube with those of the older tubes. The screen-grid tube, 222, gives an amplification at broadcasting wavelengths of from 25 to 50, the older type, the 201A, gives about 8 at all wavelengths. On very high wavelengths the 222 may give an amplification as high as 200, but this is unusual. The 222 may also be used in a voice amplificer, when it amplifies about 35, in this connection the 210A never gives more than 8. The 222 also uses much less current, about half as much as the other type, and may under certain conditions be used as an A. C. tube. At the time of writing this account no quotation could be obtained on the price of these tubes, but even though the price may be high, they will probably cut the cost of operating a set by giving better results with fewer tubes.