The Raytheon Rectifier

By Miles Pennybacker*

ALMOST every radio amateur at one time or another has asked himself why the S-tube idea could not be developed and applied to commercial B-battery eliminators. Perhaps he will be somewhat surprised to learn that this work has been going on for the past three years and that satisfactory models of such a rectifier were put under test over a year ago.

The new tube is known as the Raytheon Rectifier and already several companies are in production on specially designed parts as well as complete B-eliminators.

Before going into the qualities of the tube it may be worth while to review some

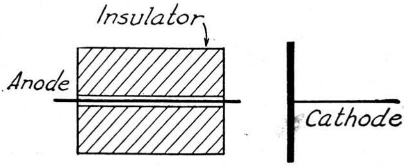

FIG. 1

of the fundamental electrical laws that have made it possible, and to look into the history of its development. To make a rectifier commercially practical, it was necessary to eliminate the major difficulties that have handicapped the old style rectifiers. These older types were invariably characterized by one or more of the following drawbacks:—

Short life.
Low current output.
Low voltage output.
Poor regulation.
Poor rectification.
Instability, or changing characteristics.

It was apparent that to get away from these hazards a new departure must be made along radically different lines. This Mr. C. G. Smith determined to do some five years ago, and he was rewarded by the discovery of the "short path principle" which may be said to be the foundation upon which the Raytheon rectifier is built. By the application of this principle he has been able not only to move entirely free from handicaps of thermionic emission and chemical conduction, but also to make sensational advances in the design of gaseous rectifiers.

This short path principle, like most fundamental laws, may be stated in very simple words—"A rarified gas is an excellent insulator between points which are in close proximity." This of course is in absolute contradiction to what one would expect, since every one has observed that the nearer two oppositely charged electrodes are to one another, the more readily a spark jumps between them. But let us consider what causes this sudden flow of current.

When a difference of potential exists between two cool metallic surfaces separated by a gas, the few free electrons that are in that gas move toward the anode at a rate dependent upon the potential gradient, or volts per inch, along the gap. The current due to these free electrons is so small as to be entirely negligible, since neutral atoms and molecules of the gas are in an overwhelming majority over the active electrons. As the gap is decreased, the potential gradient is increased and these relatively stationary molecules are bumped harder and harder by the successive collisions of the electrons on their way to the anode. Now as the gap is shortened still more a point is reached where the electrons attain sufficient velocity between collisions to knock off an electron from a gas ion, thus vastly multiplying the number of positive and negative particles. The gas by this sudden change has now become an excellent conductor. In fact its resistance may be so low as to be comparable to that of a good metallic conductor.

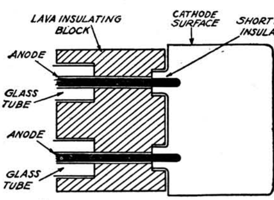

FIG 2a

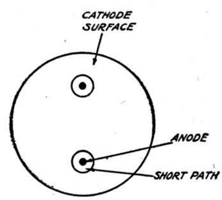

FIG. 2b

This phenomenon of gaseous conduction is seen to be dependent upon the electronic collisions with atoms which produce ionization, since there can be no appreciable conduction without ionization.

Hence, if the gas pressure is reduced so that the distance between molecules is enormously large compared to their diameters, and if the electrodes are sufficiently close together that an electron traveling in a straight line between them stands a very slight chance of striking a molecule, the ionization will be practically nil. Even a very marked increase in voltage will not

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cause a current flow since the number of electronic collisions with molecules is negligible. So we now have a gaseous insulator that is dependent only upon its dimensions and not upon voltage for breakdown.

But why this principle is of such great importance in a rectifier is still another story, and one that is just as strange in

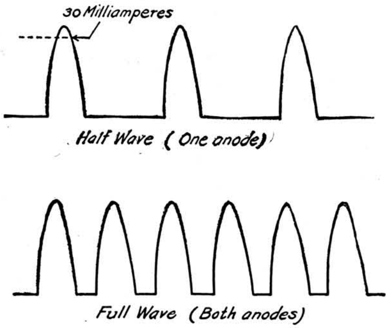
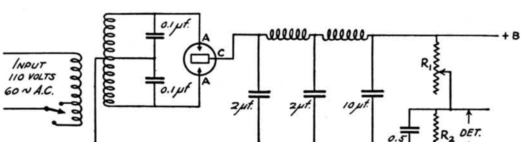


FIG. 3 SHAPE OF CURRENT WAVE BEFORE BEING FILTERED

many of its details. Let us see where it is applied.

It is a well known fact that in a gaseous tube which has one electrode larger than the other the current will flow readily when the large electrode is negative, but less current will flow when the polarity is reversed and the smaller electrode is made negative. The effect becomes more and more pronounced as the smaller electrode is reduced in size, until a point is reached at which the current in one direction becomes absolutely negligible, and we have a rectifier with no objectionable "back current". The practical difficulty is to keep the anode surface small, as some sort of conducting metal is necessary to join it to the external terminal, and unless this portion of the conductor is well insulated it will take a large share of the back current discharge. It would seem easy to insulate all but the very tip, as in Fig. 1, but as yet no insulating material has been found



R_1 is a variable carbon resistance of 10,000 to 100,000 ohms
R_2 is a fixed resistance of 10,000 ohms

FIG. 4

that would satisfactorily stand up under the temperature and the disintegrating effect of intense discharge in such close proximity.

It is here that a good insulating ring was needed to withstand the strains near the tip, and the short path principle literally stepped in to fill the gap.

Figs. 2a and 2b illustrate diagramatically the way the anodes are insulated from the cathode in the Raytheon tube. The "little tin hat" which gives the tube its unique appearance is shown in cross section in Fig. 2a. The entire inner surface of this hat is the cathode, but it has been ingeniously shaped to utilize the short path principle as an insulator. Since the discharge cannot pass between the parts which are in close proximity, only the tips of the anodes are struck by electrons, therefore the lava insulator is far enough away to be free from the disintegrating effect of the high local temperature.

Not only does this expedient establish the reliability and life of the insulator, but by making possible a decrease of effective anode area and eliminating the back current even more important results are achieved. In fact, it is in the deleterious effects of back current that other types of

THE RAYTHEON RECTIFIER TUBE

gaseous rectifiers have generally met defeat. The limitation of space prevents more than a mere enumeration of the inherent drawbacks of back current. These may be listed in the order of their importance as follows:

Disintegration of the electrodes and shortening of tube life.

Extreme difficulty of filtering out hum.

Low voltage output.

Low current output.

Poor regulation.

Fig. 3 shows an oscillogram of the current in one anode of the Raytheon. No trace of back current is discernible, as the wave does not fall below the zero axis.

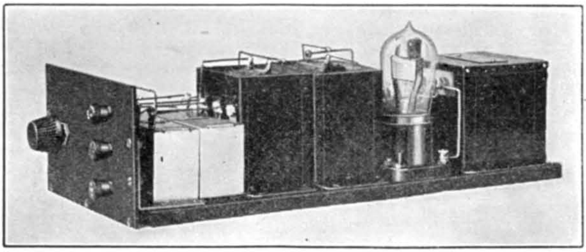
Still another feature of the construction shown is the totally enclosed cathode. By this expedient the discharge is entirely controlled and directed, whereas by any other construction it would be free to wander around the surfaces within the tube, building up static charges and producing noises in the set.

Since it was thus possible to limit the discharge to one definite area, a special study was made with a view to obtaining a surface of best operating qualities. During the past three years, under the direction of Dr. V. Bush of Massachusetts Institute of Technology, a special heat treatment has been developed that not only lowers the voltage drop within the tube but so effectually prevents disintegration of the metal that the life of Raytheon tubes under normal usage has been lengthened many years. In fact, under continuous operation at 50 milliamperes output there has been no sign of diminishing life after 10,000 hours of test.

But there is still another feature that the wide-awake radio fan will look for before buying or building a set particularly designed for this tube, and that is regulation.[1] In other words, assuming that the tube will deliver sufficient voltage and current to take care of his present five tube set, what will it do on the ten tube superheterodyne that he may purchase later in the season? Furthermore, what about operating the new high-voltage tubes that are now recommended for the last stages of audio frquency amplifiers? The Raytheon tube will deliver a voltage as high as 150 if required, and will sustain its delivered voltage remarkably well under various current loads. How well the voltage is maintained is partly a function of the filter circuit, but with the transformers and chokes designed for this tube,[2] a regulation curve similar to that shown in Fig. 5 may be expected. This curve shows the voltage variation at the output terminals of the filter circuit, in other words the plate supply voltage to the radio set, when from one to twenty tubes are used. It will be found far superior to a thermionic characteristic under the same conditions.

Fig. 4 shows the circuit particularly recommended for use with this tube. Professor F. S. Dellenbaugh, already well known to the readers of *QST*, has taken a leading part in the development of this circuit, particularly with regard to the use of 0.1 microfarad condensers across the transformer secondary. The values of capacity in each of the three legs of the filter circuit are not critical, but any wide variation from the suggested values of 2, 2 and 10 are not advisable. There are some six manufacturers on the market with specially designed transformers and choke coils, all of which give good results. All metal cases should be grounded to the "—B" terminal.

With reasonable care in the selection of parts and in construction, this B—eliminator will be found to produce excellent results on any type of receiver. The first cost is practically th last, thanks to the long life of the Raytheon rectifier.



A RAYTHEON RECTIFIER AND FILTER UNIT FOR "B" BATTERY ELIMINATION

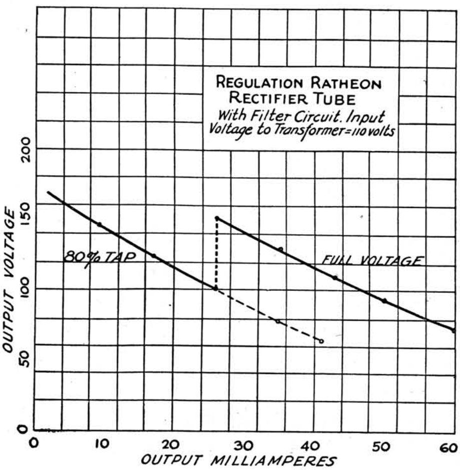


FIG. 5

Curve showing regulation of transformer, Raytheon Tube and filter; 1. e., the regulation of the complete battery substitute.

1. The meaning of "regulation" can be explained as follows. Suppose that the rectifier-filter delivers 50 milliamperes at 150 volts to a receiving set. Now if we disconnect the receiving set the voltage of the rectifier-filter will go up a little. Suppose that it becomes 160 volts, 10 volts higher. We then say "The regulation from full-load to no-load is 10 volts."

We can also say, "The regulation from full-load to no-load is 7½%. Usually we say only, "The regulation is 7½%."

The same rule fits other electrical and mechanical devices, no matter whether we are speaking of voltage, current or speed.—Tech. Ed.

2. The parts, as well as the complete battery-substitute, will be marketed by several makers before this issue of *QST* is on the newsstands.