The Raytheon "A" Rectifier

A New Development in High-Current Rectification

By JAMES MILLEN

THE rectifier described in this article is a genuinely new development which promises to have wide application in the radio field. It is different, in both appearance and operation, from anything previously in use for battery charging and "A"-socket-power service; so the following complete description of its characteristics will be of interest to all of our readers.
—EDITOR.

TO many people a rectifier may mean anything from a chemical cell to a Tungar bulb. Actually, it is any device that offers to the flow of an electric current more opposition, or resistance, in one direction than it does in the opposite direction.

Thus, by the aid of a suitable rectifier, we are able to obtain a uni-directional current flow from our house-lighting circuit, should it be (as is most generally the case) what is commonly known as alternating current. This uni-directional current is essential for battery charging and many other radio uses. A good rectifier is, therefore, quite an important device to the radio set owner.

Rectifiers are of many different types and of many different degrees of reliability and efficiency. Some are of the mechanical variety, such as sets of contacts that reverse the connections of the power line every time the direction of the current changes. Chemical cells form another class; and the so-called bulbs of both the gaseous-conduction and the incandescent-cathode types form still other classes.

An ideal rectifier might consist of a short length of wire or rod which would offer almost infinite resistance to the passage of an electric current in one direction, and practically zero resistance to the passage of current in the opposite direction. Such a rectifier would be highly efficient, compact, durable, silent in operation, long-lived and perhaps low in first cost.

A METALLIC-CONTACT RECTIFIER

Working in his small laboratory near Paris, M. Henri André, the well-known French physicist, had devoted many years of his life to the development of a rectifying device which operated on an entirely new and different principle from any previous form. Due, however, to his limited facilities, he was encountering great difficulty in bringing his invention to a final satisfactory commercial form. About this time Laurence K. Marshall, of the Raytheon Company, was traveling in France and met Prof. André. Just as years before Mr. Marshall had seen the possibilities of the present-day Raytheon tube in the crude hand-made experimental gaseous-conduction rectifiers of the American physicist, C. G. Smith, so did he realize the importance of Prof. André's new type of battery-charging rectifier.

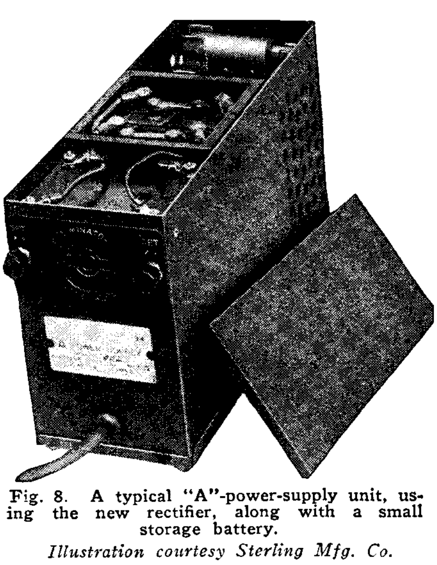

Fig. 8. A typical "A"-power-supply unit, using the new rectifier, along with a small storage battery.
Illustration courtesy Sterling Mfg. Co.

As a result, Prof André came to America and spent a year in Cambridge, Mass., working with C. G. Smith, Dr. V. Bush, director of electrical engineering graduate research work of the Massachusetts Institute of Technology and many other engineers and scientists in one of the most completely equipped research laboratories in the country.

Here his work progressed rapidly, until a final commercial product, of even greater electrical merit than had been at first possible, was finally evolved.

INSIDE THE "A" TUBE

The new device is a small, rugged steel tube hardly larger than one's thumb.

What is inside of this small copper-plated steel tube? Let us look at Figs. 1 and 2.

First there is the outside steel shell, B, in the bottom of which is fastened a silver rivet contact A. The purpose of this silver rivet is to insure the best of electrical contact between the steel tube and the granular silver anode S, which is closely packed around the alloy cathode, (C). Concentrated C.P. sulphuric acid paste is mixed in with the porous silver anode and is thoroughly dehydrated in order to prevent undesirable chemical reactions. The remainder of the structure consists of suitable washers or discs of different materials (E) for confining the parts in the proper place, a spring D to keep the anode and cathode together under the correct pressure, the cathode lead wire, and the bakelite cap G, with cathode terminal, F.

As just described, there are two metals; a porous anode of pure silver, connected to the casing, and an alloy cathode connected to the central projection are brought into contact on the inside. The porous anode contains in its interstices the non-conducting agent (sulphuric acid) which has free access to the junction between the metals. The presence of this agent preserves the junction in an "oriented" condition, but the actual conduction is through the metals themselves.

The presence of the non-conducting agent not only creates the oriented condition, but preserves this function; and the unit will continue to operate properly even after abuse in the form of excess momentary potential or current.

There is much yet to be learned in regard to metallic conduction, and the behaviour of electrons in solids is not at all clearly understood. Hence a clear explanation of the exact nature of this oriented condition is indeed difficult. Still, there are some theories on electron behaviour which

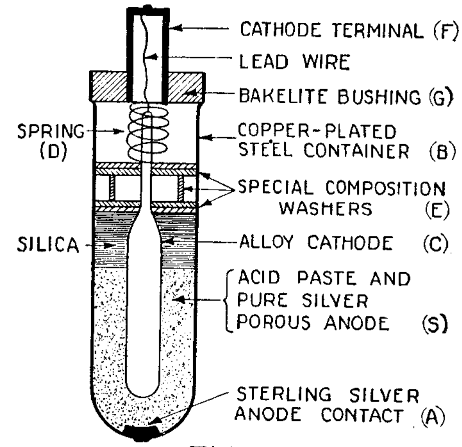

FIG. 1

This cross-section drawing of the rectifier cartridge shows the arrangement of the parts clearly.

are taking shape; and the explanation which follows appears to be reasonable.

To quote from a report by Dr. Bush: "All materials contain electrons, distributed in orbits about the nucleii of atoms. When conditions are such that electrons may with ease pass from an orbit about one nucleus to an orbit about an adjacent nucleus, a motion of electrons through the material is readily produced and we have an electrical conductor.

"Metals have this property in large degree and are hence good conductors. When two metals are in contact, a similar interchange of electrons ordinarily takes place between the adjacent atoms of the two metals, and conduction readily occurs in the two directions. A proper choice of metals, however, in the presence of a suitable agent, may set up a condition in which this property is oriented or unilateral.

"Briefly, this may possibly occur because electron excursions of one metal are much extended in the presence of the agent, while the excursions of the other are inhibited. In this condition the far-extending electrons readily pass to the opposed metal and conduction occurs, while for a potential in the other direction there is no overlap of orbits and the device insulates."

Undoubtedly the complete story of the action is more complicated than this, and no one at present pretends to understand

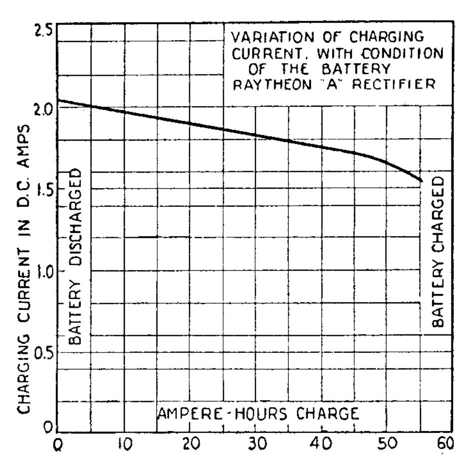

Fig. 7. How the charging rate automatically tapers off, as the battery approaches a fully-charged condition.

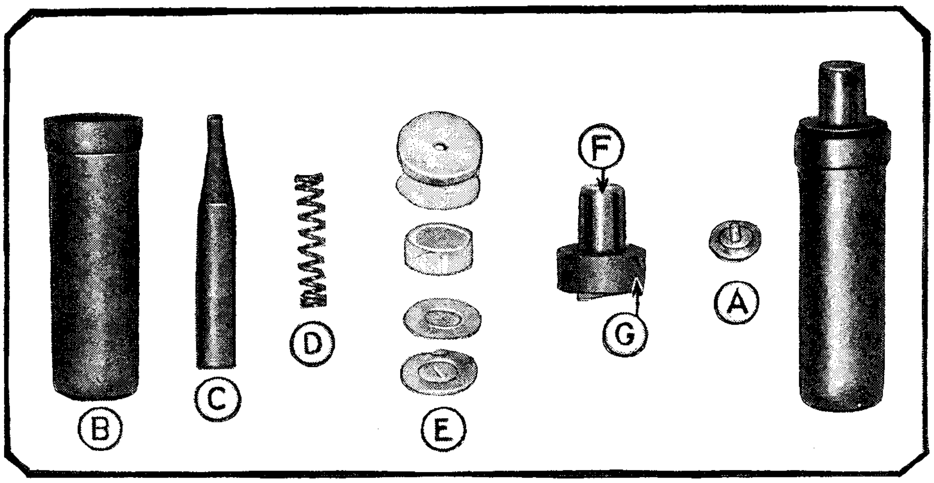

Fig. 2: The component parts of the rectifier. B, steel container; C, alloy cathode; D, spring; E, washers; F, cathode terminal; G, bakelite bushing; A, anode contact. At the right is shown a completely assembled unit.

all that goes on at an electrical contact surface.

USES FOR THE NEW RECTIFIER

At this time the new tube has two important uses in battery chargers and in "A" socket-power units. In fact several well-known manufacturers have already placed chargers and "A" power-supply devices employing the new rectifier on the market.

Due to the fact that the conduction is metallic, the internal electrical resistance of the rectifier and the power, or I^2R losses in the rectifier, are exceedingly low and thus its efficiency is quite high. The efficiency of a charger employing the new rectifier is in the neighborhood of 60%. This, as charger efficiencies go, is unusually high. Aside from the saving in power consumed, which may amount to as much as from $6.00 to $10.00 a year, the higher efficiency of a charger of this type permits it to be constructed with exceedingly compact, and thus less expensive, parts.

Only a tube, a fuse and a transformer, as indicated in Fig. 3 are required. As no energy worth mentioning is wasted in the rectifier, it may be made quite small and, as the transformer does not have to supply a great deal of useless energy, its core need not be any larger than those of some high-quality audio amplifying transformers.

Such a charger will have a maximum charging rate of 2½ amperes. By utilizing two tubes in a full-wave rectification circuit, as shown in Fig. 4, the maximum charging rate is increased to five amperes.

BEST CHARGING METHODS

Storage battery manufacturers tell us that as far as the life of the battery itself is concerned, the ideal charging system would consist of a high-rate initial charge (to remove any sulphate formation on the plates and to reduce greatly the time required for the complete charge), followed by a gradually-decreasing rate of charge in order to prevent excessive gassing and thus slow disintegration of the positive plates as the charge nears completion.

In the better service stations this feat of high initial charging, gradually tapering off, is accomplished by manually regulating the charging rate, as the state of charge of the battery changes, by means of field rheostats on the motor-generators employed for charging.

Because of the high efficiency of chargers utilizing the new rectifier, which permits of low secondary voltage, the variation in battery back-voltage, as it approaches its fully charged condition, is a large percentage of the total effective voltage of the circuit.

Thus the current flow, which is governed by the difference in the impressed voltage and the back-voltage, will be appreciably lessened as the battery voltage rises. (Fig. 7).

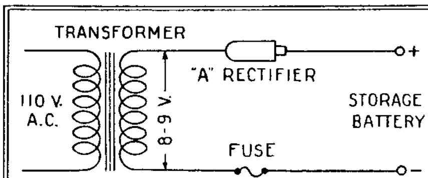

FIG. 3

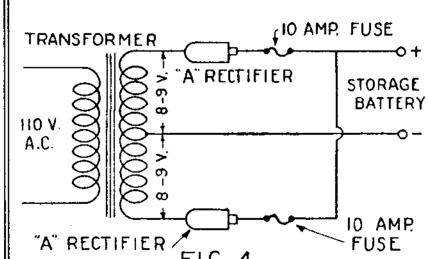

FIG. 4

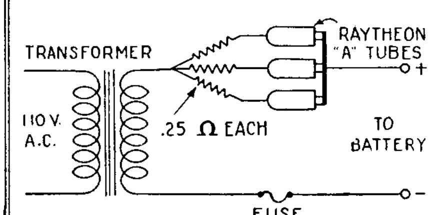

FIG. 5

Above: How the rectifier is used in half- and full-wave rectifier circuits for battery charging.

In some types of chargers, where the secondary voltage is from 20 to 30 volts, the rise in back-voltage as the battery reaches its fully charged condition is but a small percentage of the total impressed voltage.

Still other advantages than a pronounced taper-charge rate and a high electrical efficiency of chargers employing the "A" tube as a rectifier are low first cost, compactness, low operating temperature and silence in operation.

DESIGN OF CHARGERS

With so many prominent manufacturers making complete chargers for use with the new rectifier, the main features of their design will, no doubt, prove of interest.

By reference to Fig. 3, it will be seen that the only parts required are a transformer, a rectifier cartridge, mounting clips, fuse, leads, and case. The transformer may be any well-made unit of about 25 watts capacity with a low-resistance secondary having an open-circuit voltage of between 8 and 9. In the case of the double-wave charger the transformer should be rated at about 50 watts and have two 8-9-volt low-resistance secondaries connected in series, or one 17-18-volt secondary with mid-tap.

Although the rectifier will function when mounted in any position, its life is sometimes increased if operated with the small end up.

One of the fuse clips which support the rectifier should make contact with the body of the tube and the other with the small cylinder projecting from the top. The small cylinder (cathode) should be connected to the positive output circuit and the body of the rectifier (anode) connected through the transformer to the negative.

In the half-wave charger, a fuse of not over 10 amperes capacity must be connected in the charging circuit, to prevent damage should the output of the charger become short circuited or the battery be connected in the reverse manner. A 20-ampere fuse should be used with the full-wave charger. The small automobile cartridge fuses are excellent for this purpose.

Perhaps it may occur to some readers that a charger with variable rate may be readily constructed from a transformer with a higher secondary voltage than that described by inserting a rheostat in series with the tube. Such is not the case. The maximum back-voltage that the tube will withstand continuously without injury is 22 volts. As there is no current flowing during the half-cycle in which the battery is not charging, the IR drop becomes zero and the back voltage becomes equal to the peak A.C. secondary voltage plus the battery voltage. Thus, for long tube life,

(Continued on page 176)

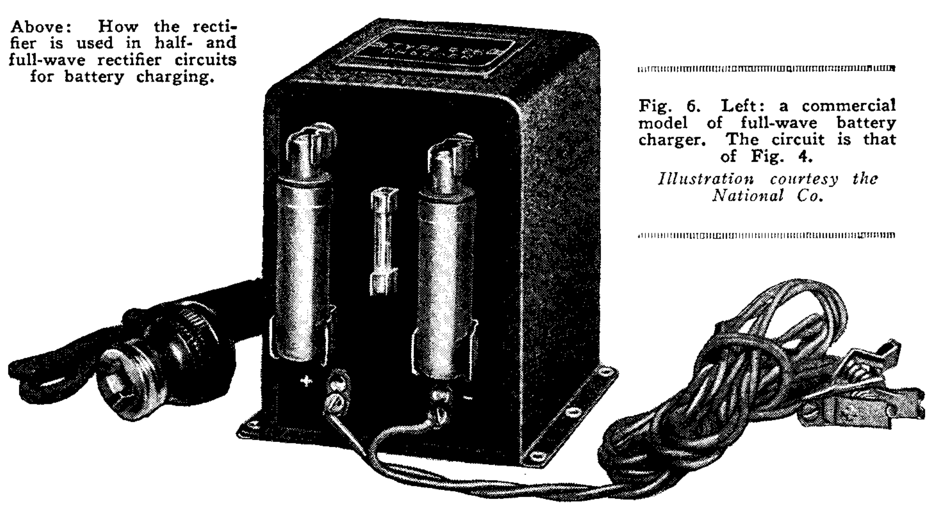

Fig. 6. Left: a commercial model of full-wave battery charger. The circuit is that of Fig. 4.

Illustration courtesy the National Co.

The Raytheon "A" Rectifier

(*Continued from page* 129)

transformer voltages must be limited to 8 or 9 volts at no load. (Peak A.C. voltage $= RMS \times \sqrt{2}$).

HIGHER CHARGING RATES

When a single "A" tube is used to rectify currents in excess of 2½ amperes, its life is reduced. For currents up to five amperes, the full-wave rectification circuit, utilizing two "A" cartridges, is recommended.

Still higher currents may be handled by operating a sufficient number of the recti-

fiers in parallel so that none is overloaded. In order to distribute the load evenly among the various tubes in such a circuit, a ¼-ohm ballast resistor (which may be a three-inch length of No. 18 nichrome resistance wire) should be connected in series with each tube as shown in Fig. 5.

COMMERCIAL FORMS OF CHARGERS

The charger shown in Fig. 6 is so designed as to be used either as a half- or full-wave charger. As a half-wave charger, only one rectifier unit is plugged in, while as a full-wave outfit two are employed. The charging rate with one rectifier is approximately 2½ amperes and with both tubes 5 amperes.

THE "A" SOCKET-POWER UNIT

Just what the final solution of the "A" power problem will be remains to be seen. Some new sets will be built to use the several new types of A.C. tubes. Many other new sets will be built to utilize the highly-perfected and yet inexpensive -01A tubes with their filaments series-connected for operation from a high-voltage, high-current rectifier of the gaseous-conduction type (such as the Raytheon BA, described by Arthur H. Lynch and the writer in the June issue of RADIO NEWS.)

But what of the hundred of thousands of sets now in use? Many will continue to use battery power, and with a good battery and a silent and efficient charger, such as those just described, will give excellent results. Some few of these sets may be rewired for series-filament power-unit supply. Some few may also be converted for A.C. tube operation.

The great majority, though, will either continue to operate from batteries, as they were originally designed to, or else from a power unit so designed as directly to replace the "A" battery without any changes whatsoever to the receiver itself.

With this in mind, several manufacturers have developed a new form of "A" socket-power unit, the heart of which is the new rectifier used in the new chargers.

There are many tricks in the successful design of such devices, however, and the development of suitable filter circuits has been exceedingly difficult. The present commercial units employ several chokes with quite low inductance and exceedingly low D.C. resistance. Instead of ordinary condensers, special dry-paste cells offering a very high D.C., and at the same time extremely low A.C. path, are employed.