A Full-Wave Mercury-Vapor Rectifier Tube

A New Rectifier for Low-Power Supplies

By Paul Schwerin*

THE development of a full-wave mercury-vapor rectifier tube of the 280 type has been brought about by the demand for a rectifier of low voltage drop and high efficiency for use in broadcast receiver power packs and in plate supply units for low power transmitters. Its application in the latter service should be particularly interesting to amateurs who use transmitting tubes requiring plate voltages up to 500 and plate currents as high as 300 ma. Although it is particularly intended to replace the Type '80 vacuum tube, in many rectifier units rated at 500 volts and less a single mercury-vapor type 280 can be used to replace a pair of half-wave Type '81 vacuum tubes. Reducing the filament voltage from 7.5 to 5.0 volts would be the only modification necessary, providing the plate

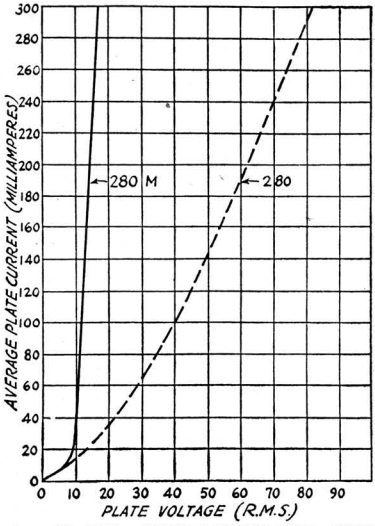

FIG. 1.— PLATE VOLTAGE-PLATE CURRENT CHARACTERISTICS OF TYPE '80 AND TYPE '80-M FULL-WAVE RECTIFIER TUBES

voltage to be rectified does not exceed the rating of the mercury-vapor tube.

In general it may be stated that the ideal rectifier would be one which would transform alternating current to direct current with perfect rectification and no loss of energy. In order to bring out the advantages of the 280-M mercury-vapor rectifier, let us examine and compare it with the vacuum type 280 rectifier.

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In a rectifier of the vacuum type we find that we are greatly limited and hampered by the space charge. To state this in a somewhat dif-

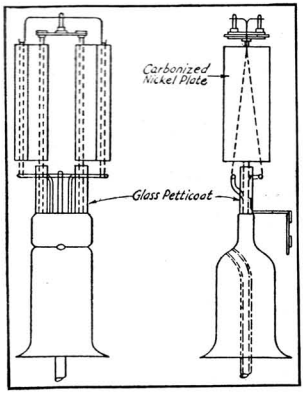

FIG. 2.— IN THE MERCURY-VAPOR TUBE SPECIAL PRECAUTIONS HAVE BEEN TAKEN TO ELIMINATE BREAK-DOWN AND ELECTROLYSIS

The plate leads are surrounded by glass "petticoats." Half of the filament is inside each plate, the two halves being connected in series.

ferent way, there is a concentrated cloud of electrons surrounding the filament. This dense accumulation of negative charges varies in depth with the plate voltage. Low plate voltages remove the charge slowly while higher values act on a greater number of electrons. The electron flow is a measure of the rectified current. The chart of Fig. 1 gives a visual conception of the current flow in relation to the applied voltage. In the vacuum type 280 tube considerable voltage is required to move the current to the plate, the broken curve showing this to be 50 volts at 140 ma.

In an atmosphere of ionized mercury vapor or other gas, there is present a considerable positive charge which neutralizes the negative space charge around the emitter. Because of this condition, the electron cloud is not as concentrated as in the vacuum type tube. Thus the emission from the filament is available without so great a loss of voltage. The volt-ampere characteristic of the mercury tube is shown by the solid curve and proves that the voltage is quite constant for large variations in load current, the average voltage drop through the tube being about 17 volts for all loads from 20 to 300 ma. The mercury vapor rectifier therefore can be looked upon as a device having a nearly constant voltage drop of 17

volts and through which all of the additional voltage supplied by the transformer can be made available for useful work in the external circuit.

The ratings of the mercury-vapor Type '80-M and the vacuum Type '80 are the same excepting

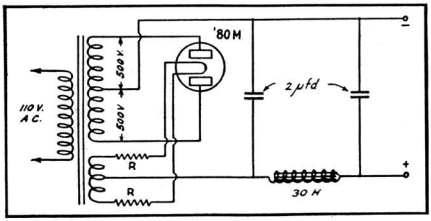

FIG. 3. — THE FULL-WAVE RECTIFIER CIRCUIT USED FOR AN AMATEUR TRANSMITTER

The resistors, R, are used to drop the filament voltage from 7.5 to 5.0 volts and are each 1.25 ohms.

plate voltages and currents. A side-by-side comparison of the two types shows the following:

	Type '80	*Type '80-M*
Filament voltage	5 volts	5 volts
Filament current	2 amps	2 amps
A.C. volts per plate (max. r.m.s.)	400	500
Total output current (max.)	110 ma.	300 ma.

The maximum inverse peak voltage rating of the Type '80-M is 2000 volts and the peak current rating for both plates is 1 ampere (500 ma. for each half of the filament). Since the tube is intended for use with a capacity input filter, the above output ratings may seem overly generous. Actual tests on sample tubes over an operating period well in excess of 1000 hours have shown that the tube is capable of withstanding

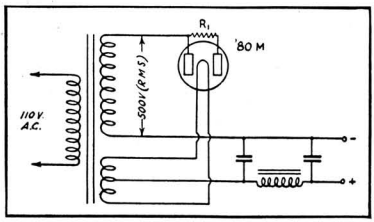

FIG. 4. — HALF-WAVE RECTIFIER USING THE TWO PLATES IN PARALLEL

The resistor R_1 is necessary to make equal the potential between the two plates and the two halves of the filament. The method of determining its proper value is explained in the test.

load currents and a.c. voltages even higher than those at which it is rated, however, even with the plate and filament power switched on simultaneously. But the above ratings should not be exceeded in general service if the maximum tube life is to be obtained.

The Type '80 rectifier is usually used at a load of about 0.125 amps. At this point the voltage drop through the tube is approximately 47 volts. This means that under these conditions there is a power dissipation loss in the tube of 5.88 watts which is not usable in the external circuit. At higher current values the voltage drop becomes correspondingly greater.

In the mercury-vapor tube, with the same power dissipation in the bulb, the load current is 0.346 amp. Comparing the useful power available in each tube, we have for the '80 tube 0.125 amps × 450 volts equals 56.25 watts, less the power loss in the tube of 5.88 watts, or 50.37 watts; while in the mercury tube with the same loss in the tube we have 0.316 amps × 500 volts equals 158.0 watts, less power loss in tube of 5.88 watts, leaving 152.12 watts avai able for use in the load circuit. The voltage available with the 280 would be 450–47 or 403 volts, while the voltage available with the mercury-vapor tube would be 500–17 or 483 volts. This means that we have approximately three times as much power available with the mercury tube as compared to the vacuum tube, when the power dissipated in the tubes is the same.

The inverse peak voltage, which is destructive because of its magnitude during the non-current cycle of the rectifier, is on the order of three times the value of the average (d.c.) voltage. To overcome any tendency to break-down in the stem, the elements of this tube have been protected by means of small diameter tubing surrounding the plate leads as shown in Fig. 2. This breaks up the mercury film which is apt to form across the press, and introduces a long glass path to get the required insulation.

Tubes have been run in the laboratory for a considerable period of time at 550 volts; possibly 600 volts would not be injurious. However, we believe it is more practical to take out the power at high current rather than at high voltage.

The Type '80-M tube has been used for some time in the plate supply for an amateur transmitter, furnishing plate power to an oscillator-amplifier set using Type '10 tubes, the single mercury-vapor tube being substituted for a pair of Type '81 tubes around which the unit had been originally built. The circuit diagram of the unit is shown in Fig. 3. Using the two '81's, the filter terminal voltage was 450 volts at a load of 100 ma. With the '80-M replacing these, the d.c. voltage jumped to 550 at the same load current. Increasing the load current caused a drop from this voltage value, of course, because of the resistance of the filter. In this particular unit the rectifier filament supply was on the same transformer with the plate winding and it was necessary to switch on both supplies simultaneously. In spite of this rough treatment there has been no apparent damage inflicted on the tube, although it is recommended that a separate filament supply be provided so that the filament power may be switched on several seconds before the plate voltage is applied.

At the usual current values obtained in amateur transmitters, one '80-M rectifier could be used in a 500-volt plate supply for a transmitter using a Type '10 oscillator, a Type '10 buffer, two Type '10's in a push-pull class-C amplifier, and a pair of Type '50 modulators.

The rating of 150 watts useful power out of the tube is based on the same bulb radiation as is common in vacuum Type '80 tubes. If a more favorable position for heat radiation is utilized, the bulb and glas parts may be kept at a sufficiently low temperature to prevent electrolysis when greater power is taken from the tube. As long as the glass parts are kept sufficiently cool, no great danger will be experienced by taking out 300 ma. for useful work in the circuit. A special glass has been utilized in the construction of the stems in these tubes so as to cut down to a minimum trouble which might arise from electrolysis.

It will be readily seen from a study of the curves that the regulation in the circuit utilizing mercury-vapor tubes will be a great deal better than with vacuum tubes, because the voltage drop through the tube remains fairly constant with large variations in load.

PARALLEL OPERATION

It is possible to use this tube as a half-wave rectifier using both plates in parallel. However, in this case it will be necessary to place a resistance between the two plates, as shown in Fig. 4, since it has been found that when using the plates in parallel in most cases only one plate draws current. Obviously this would make the job too hard for one of the filaments. The introduction of the small series resistance will eliminate this condition. The action is due to the drop in voltage through the filament, the plate to filament potential in one side being 2½ volts higher than in the other. The value of resistance to be used in this case depends upon the current to be drawn. For example, if the load current is 250 ma. (125 ma. per plate) the resistance would be $\frac{2.5}{.125}$ or 20 ohms. This would cause both filaments to operate uniformly and give longer life.

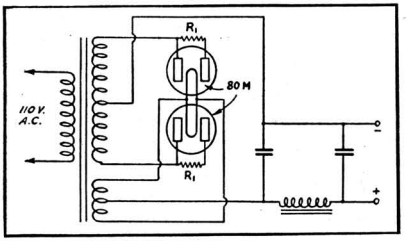

FIG. 5.—A FULL-WAVE CIRCUIT USING TWO TYPE '80-M RECTIFIER TUBES

The current rating is practically double that of a single tube but the voltage rating is the same. The resistance of each of the resistors R_1 should be 2.5 volts divided by one-fourth of the total load current.

The action of this resistance is to maintain the difference of potential between the filaments and their respective plates at the same value. In other words the resistance is placed in series with the plate which would normally have the greatest potential difference between it and its filament, thus bringing the voltage down to that between the other two elements. It must be borne in mind that these filaments are to be poled in a certain direction with regard to the filament transformer; otherwise the resistance will not cause both plates to function equally. This can be readily tested by

(Continued on page 44)

STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC., REQUIRED BY THE ACT OF CONGRESS OF AUGUST 24, 1912, of *QST*, published monthly at West Hartford, Conn., for April 1, 1931.

State of Connecticut } ss:
County of Hartford }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared K. B. Warner, who, having been duly sworn according to law, deposes and says that he is the business manager of *QST* and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, The American Radio Relay League, Inc., West Hartford, Conn.; Editor, Kenneth B. Warner, West Hartford, Conn.; Managing Editor, Clark C. Rodimon, West Hartford, Conn.; Business Manager, Kenneth B. Warner, West Hartford, Conn.

2. That the owners are: (Give names and addresses of the individual owners, or if a corporation, give its name and the names and addresses of stockholders owning or holding 1 per cent. or more of the total amount of stock.) The American Radio Relay League, Inc., an association without capital stock, incorporated under the laws of the State of Connecticut. President, Hiram Percy Maxim, Hartford, Conn.; Vice-President, Chas. H. Stewart, St. David's, Pa.; Treasurer, A. A. Hebert, West Hartford, Conn.; Communications Manager, F. E. Handy, West Hartford, Conn.; Secretary, K. B. Warner, West Hartford, Conn.

3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent. or more of total amount of bonds, mortgages, or other securities are: (if there are none, so state.) None.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear on the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements, embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association or corporation has any interest direct, or indirect in the said stock, bonds, or other securities, than as so stated by him.

5. That the average number of copies of each issue of this publication, sold or distributed, through the mails or otherwise, to paid subscribers during the six months preceding the date shown above is. . . . . .
(This information is required from daily publications only.)

K. B. WARNER.

Sworn to and subscribed before me this 20th day of March, 1931.

Alice V. Scanlan.

(My commission expires February, 1934.)

Realizing this, it appears to us to be a discourtesy for an amateur to refuse to send a QSL card to another station, when the latter specifically requests it for the purpose of applying for membership in the WAC Club. Several cases where this has happened have come to our attention recently, and we wish to deplore any such inconsiderate practice. There is little excuse for refusing or neglecting to QSL in the face of such a request.

You may need a card yourself some day!

German Notes

By Dr. Curt Lamm, *For. Sec'y D.A.S.D.*

Program of the Sixth Annual Convention of the D.A.S.D. Hamburg, May 22–26, 1931

Friday, May 22nd:	Visit to valve factories and laboratories at Hamburg, airport stations, and the aeronautical observatory.
Saturday, May 23rd:	Sightseeing trips in and around Hamburg.
20.00	Official opening. Presidential address. Welcome by the Hamburg D.M.'s, etc.
After 23.00	Visual QSO's, rag-chewing *ad infinitum*.
Sunday, May 24th:	
9.30–14.00	Meeting of the Board and D.M.'s of D.A.S.D.
14.00	Lunch.
15.00–19.00	Business Meeting. (Detailed business agenda to be published shortly before convention.)
20.00	Informal meeting. Dinner. Movies.
Monday, May 25th:	
10.30	Lectures and demonstrations on various problems connected with short-wave radio.
14.00	Lunch.
15.00	Discussion on various technical problems, station visits, stroll, etc. Exhibition of strange radio gear.
Tuesday, May 26th:	Boat Party: visit to Heligoland Island.

Again we cordially invite all foreign friends to take part in the convention, and we hope to see lots of old and new faces among our group at Hamburg. Anyone desiring to attend is requested to communicate with D.A.S.D., headquarters at Blumenthalstrasse 19, Berlin W 57, Germany.

New A. C. Relays

(*Continued from page 32*)

aluminum, the latter completely shielding the relay, since the base is also aluminum. Provisions are made for pipe connections to the relay so that the leads may be shielded as well. The action is snappy, and the relay follows all hand keying speeds very readily.

The other relay is a time-delay affair designed for controlling the power supply equipment. It is so arranged that the primary circuit of the plate transformer is not closed until the rectifier and transmitting tube filaments have had time to reach their operating temperatures. A thermal relay is connected to two magnetic relays (the latter of the same type of construction as that used in the keying relay) in such a way that the plate transformer circuit is not closed until the heater element has gone through one complete cycle of heating and cooling, thus making the time delay feature always operative even though the line switch be opened and instantly closed again. The time delay can be adjusted between 15 and 60 seconds. Both of these relays are products of the Ward-Leonard Company, Mount Vernon, N. Y.

A Full-Wave Mercury Vapor Rectifier Tube

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connecting the filaments first in one direction and then in the other. When properly connected a blue haze will be apparent inside both of the plates, instead of one.

The arrangement of two Type '80-M tubes used as a full wave rectifier will give an increased supply of current for any type of setup requiring more current. The schematic circuit of such a rectifier is shown in Fig. 5.

Experimenters' Section

(*Continued from page 39*)

put on a new pulley, or climb the pole to run the rope back through the old one.

"I made a wire basket shaped like a dog's muzzle, with the wire which forms the rim of the opening arranged like a slip noose, as shown in Fig. 9. I then fixed up a kite about 4½ feet tall, and tied the basket, from which the pulley and rope were suspended, about halfway up the kite string, maneuvered the kite over the pole, pulled the basket down over the top by pulling on the rope which passed through the pulley, jerked the kite loose, and I had a new pulley and rope placed right near the top of the pole. If a plain loop had been used instead of a basket, it might have slid down to the guy wires before tightening.

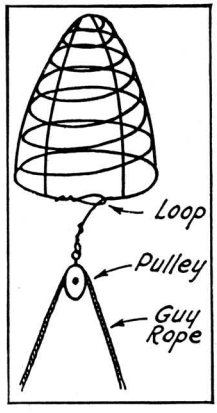

FIG. 9

"If this has never been published before the idea might be useful to some hams. It could also be used to replace broken guy wires."