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REGULATED RECTIFIER

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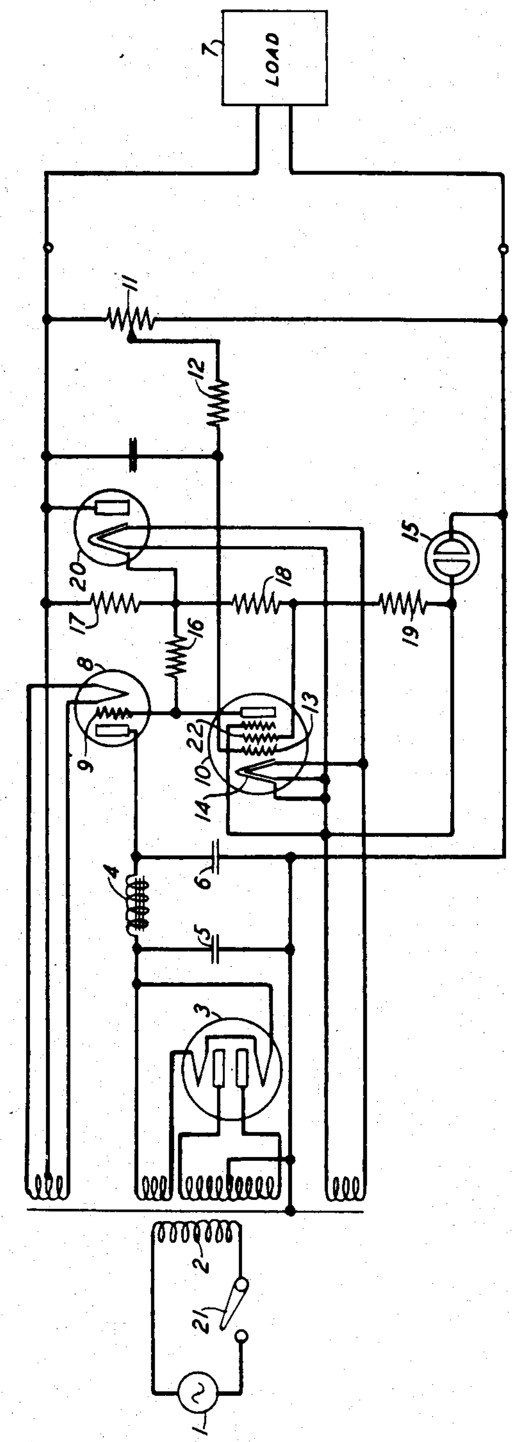

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REGULATED RECTIFIER

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This invention relates to rectifiers and particularly to the type of rectifier in which the direct output voltage is automatically regulated to a substantially constant value over a wide range of load currents and supply voltages.

In one known form of regulated rectifier, the plate-cathode circuit of a regulating tube is connected in series with the rectifier output and grid of this tube is biased in accordance with the voltage at some point along a bleeder circuit on the load side of the tube so that any tendency towards change in the output voltage causes compensating changes in the impedance of the regulating tube.

For close regulation the circuit must be very sensitive to load voltage variations and this sensitivity is usually obtained by using a pentode tube to amplify the voltage variations before applying them to the grid of the regulating tube. For convenience the cathode bias necessary for this amplifying tube is usually obtained from the voltage drop across a gas discharge tube connected across the output on the load side of the regulating tube. The filament type pentodes available are too fragile and they do not provide sufficient gain for this purpose. Moreover the heating of the filament of such a tube by alternating current would introduce ripple voltages into the regulator circuit. The amplifying tube, therefore, in general must be of the heater type. The rectifier and regulator tubes, however, are usually of the filament type since heater type rectifiers are not suitable for many applications and heater type regulator tubes of sufficient current carrying capacity are not generally available.

The principal operating difficulty experienced with rectifiers of this type is associated with the starting period when the alternating voltage is first applied. The cathodes of the rectifier and regulator tubes are quickly heated to operating temperature but the heater type control tube requires a considerably longer time to reach emission temperature. During this interval the regulator tube is not properly biased and substantially the full output voltage of the rectifier is applied to the load. Since the load usually consists of amplifiers using heater tubes the filaments of which are energized at the same time as the rectifier, the rectifier is practically without load during the interval when the regulating tube is ineffective. The no-load output voltage of the rectifier is usually more than double its full-load voltage and hence with this type of rectifier the whole amplifier system is subjected to abnormal voltage each time the equipment is started. This materially reduces the life of the equipment and requires, with a corresponding increase in cost, the use of better insulation throughout the system than is required when the voltage is being regulated.

The object of this invention is to limit the output voltage of such a rectifier to a safe value during the time required for the control circuit to become operative.

According to the invention the grid of the regulating tube is held at a suitable fixed potential during the warm-up period and the small current, which flows through the bleeder circuit as soon as the rectifier is energized, raises the potential of the cathode of the regulating tube above the fixed potential of the grid until cut-off is approached so that, by proper choice of the fixed grid potential, the no-load output voltage can be stabilized at any desired value. When the control circuit becomes operative, a bias varying with the voltage applied to the load is substituted for the fixed bias and the rectifier thereafter functions in the conventional manner.

The necessary fixed grid bias is conveniently obtained from the gas discharge tube which is connected in series with a high resistance across the output of the rectifier so as to ignite immediately when voltage is first applied to the rectifier. After the control tube becomes operative the substitution of the variable bias for the fixed bias on the grid of the regulating tube is effected by supplying plate current to the control tube through some form of delay device, such as a diode with a heating time which is preferably at least equal to the heating time of the control tube. When this delay device becomes conductive, plate current flows to the control tube under the control of the output voltage. Any variation in the output voltage will then produce corresponding variations on the potential of the plate of the control tube and the grid of the regulating tube so that the impedance of the latter tube varies in such a manner as to maintain the output voltage substantially constant.

The invention will be more clearly understood from the following detailed description and the accompanying drawing, the single figure of which shows a regulated rectifier according to the invention.

In the drawing, alternating current from the source **1** is supplied through the transformer **2** to the full wave rectifier tube **3**, the output of which is filtered by the coil **4** and condensers **5** and **6** and applied to the amplifier or other load **7** through the series regulating tube **8**. The voltage applied to the load will be somewhat less than that at the output of the filter due to the impedance of the tube 8. The bias on the grid 9 of the tube 8 and hence the impedance of the tube is controlled in accordance with the plate current of the control tube 10 and the impedance of this latter tube is determined by the voltage supplied to the load by virtue of the connection from the shunt resistor 11 through resistor 12 to the grid 13. The cathode 14 is maintained at a suitable positive potential by means of a gas discharge tube 15 or other constant voltage device. The potential applied to the grid 13 is of such a value that the plate current of the tube 10 flowing through the resistor 16 will provide the proper bias for the grid 9 of the regulating tube 8.

In normal operation, if the potential applied to the load tends to increase, the potential of grid 13 increases in a positive sense with respect to the cathode 14. The resulting increase in the plate current of the tube 10 increases the voltage drop across the resistor 16 and the negative bias on the grid 9 of the regulating tube 8 with the result that the impedance of the tube 8 increases and almost completely nullifies the tendency of the output voltage across the resistor 11 to increase. Conversely, if the voltage tends to fall below its proper level, the positive potential on the grid 13 decreases, the plate current of the tube 10 and the negative bias on the grid 9 decrease thereby decreasing the impedance of the tube 8 and maintaining the output voltage very close to its proper value.

However, when the rectifier is first energized by closing the switch 21 this automatic control is not effective since the heater tube 10 requires an appreciable time to reach emission temperature. Until plate current begins to flow in the tube 10 the resistor 16 provides no negative bias for the grid 9 of the tube 8 and without bias this tube presents only a very small impedance to the output current of the rectifier tube 3. When, as in the usual case, the load 7 consists of an amplifier with heater type tubes which also require considerable time to become operative, the only load on the rectifier during the warm-up period consists of the high impedance shunt 11. The voltage applied to the load is, therefore, substantially the full no-load voltage of the rectifier which, as stated above, may be at least double the normal full-load voltage.

In this circuit the voltage is prevented from rising to these abnormal values in the following manner: Since the gas discharge tube 15 is connected across the load circuit in series with the resistors 17, 18 and 19, it will ignite immediately when power is applied to the unit. To avoid unnecessary waste of power the resistor 17 is made very large so that the current flowing in this circuit is of the order of only a few microamperes. The resistors 18 and 19 are relatively small as compared with resistor 17 so that at starting the grid 9 of the tube 8 is held at a potential only slightly above the sustaining voltage of the gas discharge tube 15. As soon as current begins to flow through the tube 15 and the shunt resistor 11, the potential of the cathode of tube 8 will be raised above the potential of the grid 9 until cut-off is approached and a state of equilibrium is reached at some output voltage which may be approximately equal to or even below that obtained in normal operation. The voltage at which the state of equilibrium is reached may, of course, be varied over wide limits according to the requirements of each case by a proper proportioning of the resistor 17 with respect to resistors 18 and 19. The value of resistor 19 will, of course, be of the value required to provide suitable potential for the screen 22 of the control tube.

When the cathode 14 of the tube 10 reaches operating temperature it remains inactive since its plate voltage is very low due to the low values of resistors 18 and 19. At this time, however, the diode 20 is approaching operating temperature and when emission from its cathode begins, the current through resistors 18 and 19 and the gas discharge tube 15 slowly increases as the impedance of the tube 20 decreases, until full plate voltage is applied to the tube 10 and the potential of the grid 9 of the tube 8 is raised to unblock the tube and permit a normal flow of current to the load 7. When this condition has been reached the impedance of the tube 8 is regulated in the manner already described to maintain the output voltage substantially constant.

It is, of course, preferable that the diode remain non-conducting until after the control tube is fully heated but in any case the heating time of the diode should be at least equal to that of the control tube in the sense that, as these tubes begin to emit, the sum of the decreasing potential across the diode and the increasing potential across the resistor 16 shall always be sufficient to maintain on the regulating tube the bias necessary to keep the output voltage at a safe value.

While the invention has been described with reference to a particular circuit for purposes of illustration this circuit may be modified in various ways within the scope of the following claims. For example, either the gas discharge tube or the diode or both may, if desired, be connected on the rectifier side of the regulating tube, or other known means for performing their respective functions may be substituted for either or both of these devices.

What is claimed is:

1. In a voltage regulator of the type in which a source of variable voltage is connected to a load through the plate-cathode circuit of a regulating tube and in which the grid-cathode bias of the regulating tube is varied by a heater type control tube having a plate current which varies with the voltage applied to the load, means for biasing the regulating tube to limit the voltage applied to the load during the warm-up period of the control tube and a circuit connection from the source to the plate of the control tube including a device having a delay time at least equal to the heating time of the control tube.

2. In a voltage regulator of the type in which a source of variable voltage is connected to a load through the plate-cathode circuit of a filament type regulating tube and in which the grid-cathode bias of the regulating tube is varied by a heater type control tube having a plate current which varies with the voltage applied to the load, means for applying a high negative bias to the grid of the regulating tube to limit the voltage initially applied to the load and a diode tube having a heating time at least equal to the heating time of the control tube for reducing the bias on the regulating tube and conducting plate current from the source to the control tube.

3. In a voltage regulating system comprising a source of variable voltage, a voltage dividing impedance connected across the source, a filament type regulating tube having a grid and plate and filament electrodes connected in series between the source and the impedance and a

heater type control tube having a grid connected to a point on the impedance and a plate connected to the grid of the regulating tube, a high resistance, a second resistance and a gas discharge tube connected in series across the source of variable voltage, a resistive connection from the plate of the control tube to the junction of the high and the second resistances and a heater type diode having a heating time at least equal to that of the control tube for supplying plate current to the control tube through the resistive connection.

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