

Jan. 7, 1941.

C. W. HANSELL

2,228,112

CATHODE RETURN BIAS CIRCUIT

Filed May 7, 1938

3 Sheets-Sheet 1



INVENTOR.
CLARENCE W. HANSELL
C. W. Hansell
ATTORNEY.

Jan. 7, 1941.

C. W. HANSELL

2,228,112

CATHODE RETURN BIAS CIRCUIT

Filed May 7, 1938

3 Sheets-Sheet 2

Fig. 2

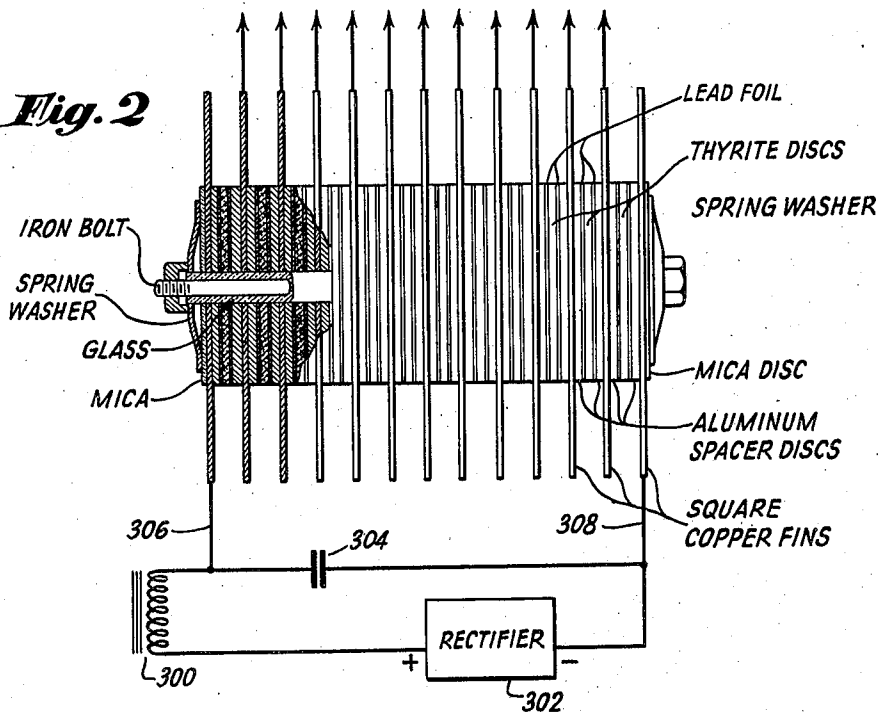
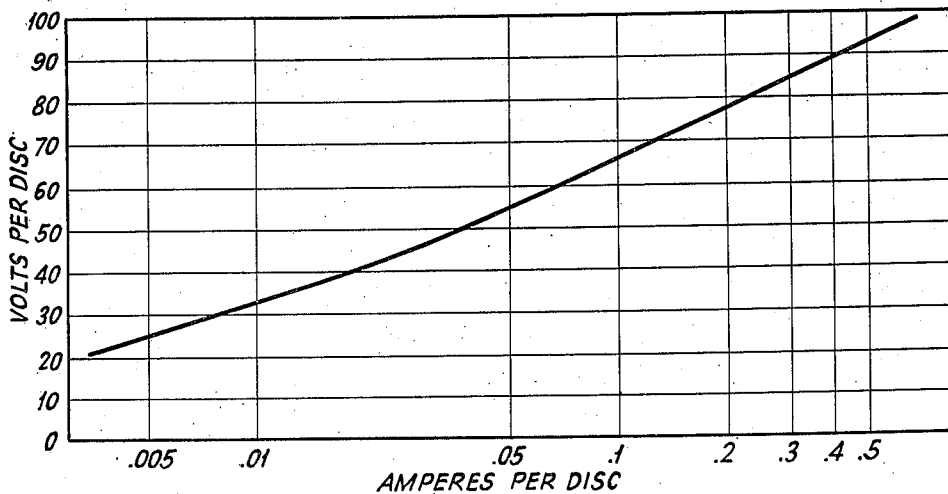


Fig. 3



BY

INVENTOR.
CLARENCE W. HANSELL
H.S. Grover
ATTORNEY.

Jan. 7, 1941.

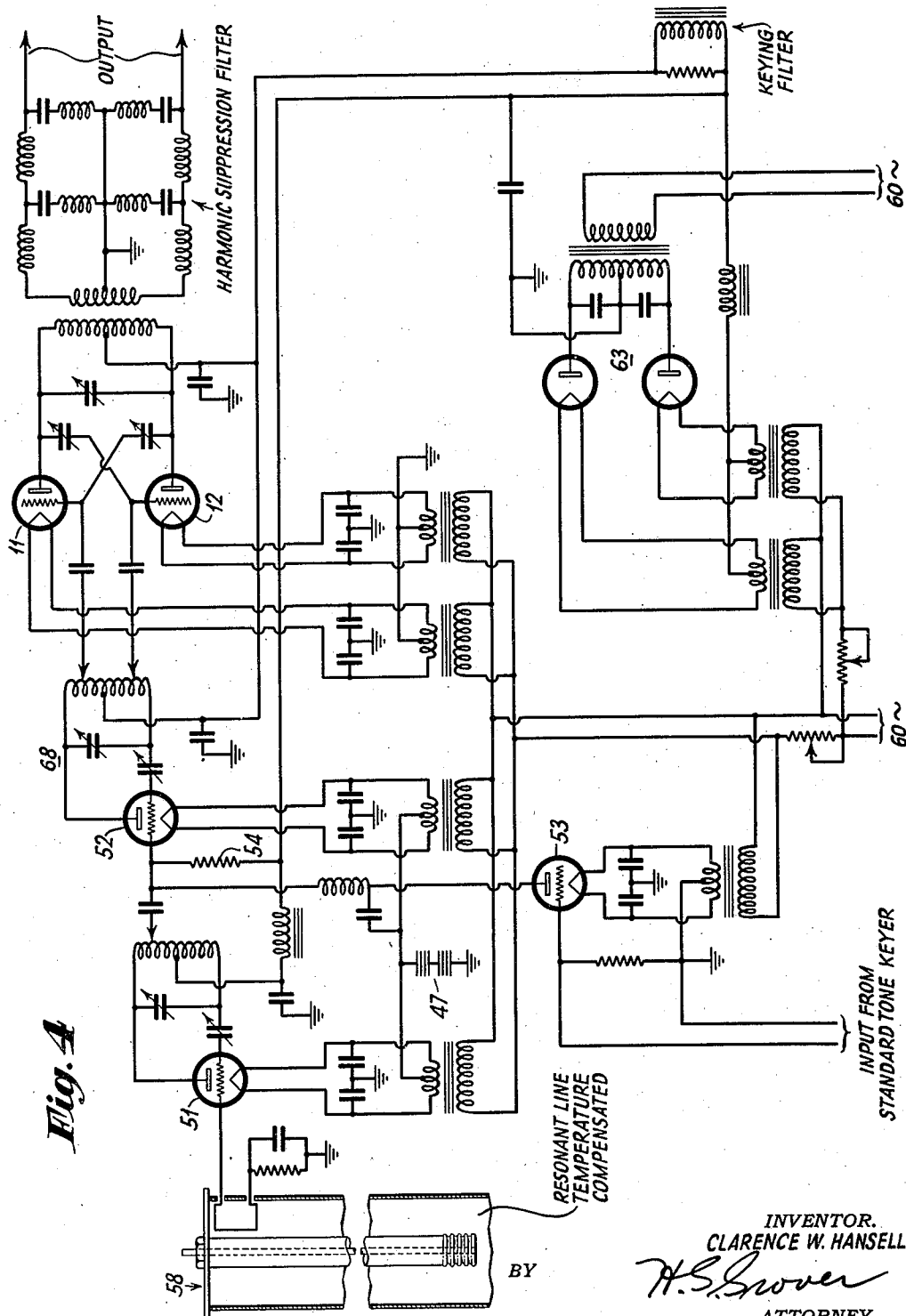
C. W. HANSELL

2,228,112

CATHODE RETURN BIAS CIRCUIT

Filed May 7, 1938

3 Sheets-Sheet 3



INVENTOR.
CLARENCE W. HANSELL

H.S. Grover
ATTORNEY.

UNITED STATES PATENT OFFICE

2,228,112

CATHODE RETURN BIAS CIRCUIT

Clarence W. Hansell, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application May 7, 1938, Serial No. 206,577

3 Claims. (Cl. 179—171)

This invention relates to a means of biasing thermionic tubes in circuits such as oscillators and amplifiers. Generally, it utilizes the variable resistance characteristics of "Thyrite."

"Thyrite" is a material which was developed by the General Electric Company for lightning arrestors and has the distinctive characteristic that the current rises very rapidly with increases in voltage impressed across it. When the voltage is doubled the current goes to something like 12 to 14 times the initial value.

References to this material will be found in U. S. Patent No. 1,822,742; General Electric Review for February, 1930; June, 1930; April, 1934 and May, 1934; and in the Transactions of the American Institute of Electrical Engineers for April, 1930.

In the past bias voltage has been obtained from separate voltage supplies such as rectifiers, motor generators or batteries. These are expensive to build and operate and introduce additional possibilities of failure.

Grid leak resistance bias has been used in the past when the tube in question draws grid current. In the case of an oscillator or amplifier, this means of obtaining bias may endanger a tube since if for any reason the oscillator stops oscillating or the drive to the amplifier fails, the bias is removed and the tube will draw excessive plate current and be subjected to excessive or destructive internal power losses or, at the least, waste energy.

Bias is sometimes provided by causing the anode current of the tube to flow through a resistance connected between the cathode and the negative of the anode current supply source, the grid circuit being connected to the negative of this supply source. This system of bias is very often undesirable in connection with tubes working class C when used in radio transmitters for services such as telegraph. In this case when the control means, which may be a telegraph key, is up and no excitation is furnished to the amplifier a relatively high value of anode current must flow to produce the bias and the power represented by this current is mostly dissipated in the tube. If a higher resistance is used then the bias and the losses in the resistor are excessive when the key is closed.

To overcome these difficulties is the main object of my invention.

Referring, now, to the drawings for a more complete understanding of my invention, Figure 1 shows a circuit diagram of my invention, while Figure 2 shows a form of construction of an ele-

ment thereof, Figure 3 is a curve explanatory of my invention and Figure 4 shows a modification of my invention.

Figure 1 of the drawings shows schematically the circuits of a class C telegraph transmitter in which my invention has been incorporated. 1 and 2 are tubes in a push-pull amplifier stage, the anode current being supplied through switch 3 and returning through ammeters 4 and 5, lead 6 and resistor bank 7 to ground and to the negative side of the anode supply. Excitation is supplied from earlier stages marked 8 to the grids of 1 and 2. The excitation is keyed in any suitable way through lead 100 in the earlier stage 28 in accordance with the telegraph signals. In normal telegraph operation the two tubes 1 and 2, assumed for purpose of illustration to be RCA-846 tubes, operate under the key down condition, that is, a marking condition with a negative bias of about 500 volts on the grids, about 6000 volts positive on the anode circuit, 200 milliamperes total grid current and 1 ampere total anode current. These tubes have an amplification factor of about 40. Even with 6000 v. D. C. on the anode only about 100 volts negative grid potential is required to limit the anode dissipation to the maximum rated value. If the filament return resistor 7 is one whose resistance varies, with the variation of current through it, in the proper direction, both the key-up condition power losses, that is in the spacing condition, and the key-down condition power losses may be decreased. We should have a resistance the value of which increases rapidly as the current is decreased. Metallic oxides, such as cuprous oxide used in photo-voltaic cells and rectifiers, for example, are materials which exhibit such a characteristic. A material manufactured by the General Electric Company for use in lightning arrestors has the desired characteristics to a marked degree. It is called "Thyrite" and is understood to be a ceramic material made by compressing and baking a mixture of carborundum (silicon carbide) and clay. The method of manufacture is described in U. S. Patent No. 1,822,742 issued to K. B. McEachron on September 8, 1931.

The current flowing through the anodes of tubes 1 and 2 and through the "Thyrite" resistor 7 causes a voltage drop across 7 maintaining the cathode at a positive potential with respect to ground. Since the grids are maintained at ground potential by virtue of being connected to ground through grid leaks 9 and 10, their potential is negative with respect to that of the cathode. A condition of equilibrium is reached in

which the bias voltage built up across 7 allows just the required amount of anode current to flow through tubes 1 and 2 to produce this bias voltage.

5 The "Thyrite" bias resistance may be adjusted to give the desired 500 volts drop at a normal total anode current of 1 ampere during marking intervals. Under spacing conditions for this adjustment the anode current will be lower than
10 the permissible safe value so the tubes will not be damaged.

A single standard "Thyrite" disc 3 inches in diameter and $\frac{3}{8}$ inch thick at about 80 volts passes $\frac{1}{4}$ ampere. If 4 of these discs are used in parallel in each of 3 series groups a resistance
15 of about 240 ohms is obtained so long as we have one ampere through them. As the current is decreased the resistance and voltage drop will vary approximately according to the following table:

	Amperes	Volts	Resistance
1	1	240	240
0.1	0.1	132	1320
0.01	0.01	51	5100

During spacing intervals a condition of equilibrium is reached in which the voltage drop across the "Thyrite" builds up the bias to a value
30 which limits the anode current to the value necessary to maintain this voltage drop. From the anode characteristics of the RCA-846 tubes and the "Thyrite" characteristics as given in Figure 3 it can be determined that this equilibrium occurs when the total anode current is
35 .08 ampere and the bias voltage, that is, the voltage drop across the "Thyrite," is 120 volts. This represents a power dissipation in the anodes of each of the two tubes of only about 240 watts and in the "Thyrite" a power dissipation of about
40 10 watts.

During the marking interval with the conditions assumed the one ampere anode current through the "Thyrite" builds up a bias voltage
45 of 240 volts. This represents a power of 240 watts to be dissipated in the "Thyrite." Thus, assuming the time to be equally divided between marking and spacing, the average biasing power is about 365 watts, all of which is supplied by the main rectifier. This is not excessive in comparison with the power which would be required if a separate bias rectifier and its loading resistor were used as in the prior art. A further definite advantage lies in the fact that since no bias
50 rectifier is required a saving in cost is effected and a source of failure and interruption of service is eliminated.

Also, since "Thyrite" is instantaneous in its resistance response to variations in applied voltage and current there is no apparent reason why
60 it can not be used to replace the bias rectifier for telephone service.

As pointed out by J. L. Finch in a co-pending application No. 173,561, filed November 9, 1937, marking interval losses in the "Thyrite" biasing resistor in the filament return of telegraph transmitters, or the continuous losses in telephone transmitters, where the high frequency power is on continuously, may be reduced by employing
70 some negative grid bias from another source. For example, a combination of grid leak bias and "Thyrite" filament return bias may be used in a way which greatly reduces the marking interval losses but which still holds the spacing interval losses to a low value.

In the above example it is assumed that the working bias of 500 volts is obtained in this manner. Thus the 240 volts built up across 7 is augmented by an additional 260 volts grid leak bias.

If, in a telephone transmitter, for example, the excitation is accidentally removed, the drop in the "Thyrite" may be the same as in the above example of a telegraph transmitter for spacing intervals and the power dissipation in the tubes will then also be the same as in that example
10 and the tubes will thus be protected from excessive dissipation. On the other hand, a wide variety of adjustments are possible under which some desired operating characteristic may be obtained, without sacrificing the tube protection
15 provided by the "Thyrite" in case of failure of excitation.

One modification of my invention is shown in the stage immediately preceding the stage 1, 2. In this stage marked "8", 21 and 22 are tubes in an amplifier, the plate current being supplied through switch 23, and return through am-
20 meters 24 and 25, lead 26 and "Thyrite" resistor bank 27 to ground and to the negative side of the plate supply. Excitation is supplied from earlier stages 28 to the grids of 21 and 22. This excitation is keyed in stage 28. For the marking condition excitation causes grid current to flow through grid leaks 29 and 30.

This current results in a negative grid bias
30 which augments the grid bias obtained by maintaining the cathodes at a positive potential with respect to the ground.

For the spacing condition the output of stage 28 may not be entirely stopped. To prevent a residual wave from coming through stage 8 tubes 21 and 22 must be biased beyond cutoff. Cathode return bias and grid leak bias alone cannot maintain these grids at a voltage beyond cutoff. To give this bias voltage, current from a D. C. voltage source in rectifier unit 31 is supplied to 27 through resistors 32 and 33. For the spacing condition a small current flows through 27, building up a voltage of about 200 volts.

In order for this to be true the resistance of 27
45 must be about 10,000 ohms. If this were ordinary resistance then for the marking condition, when the anode current flows through this resistance the voltage would be excessive. When "Thyrite" is used the voltage only rises by 50%
50 to 100% for the marking condition.

A tap is provided on "Thyrite" bank 27 which supplies bias for tube 41 by making its cathode positive with respect to its grids for the spacing condition. This protects this tube from excessive anode current which it might otherwise draw if its excitation failed.

This invention will be of value in connection with many types of electric power equipment, including rectifiers for radio transmitters, power
60 distribution systems, etc.

Reference is made to Uselman application Serial No. 103,643, filed October 2, 1936, now Patent No. 2,201,211 May 21, 1940, as illustrative of a manner in which the "Thyrite" banks 7 and 27 may be constructed. Figure 2 also illustrates one type of construction.

The stage 8 and the stage formed of the tubes 1 and 2 may be of the frequency multiplier type in which event the plate circuits are tuned
70 to successively higher odd harmonics of the excitation frequency supplied from the output of tube 41 which, also, if desired, may be made to operate as a frequency multiplier. In this event the plate circuit of tube 41 is tuned to some
75

desired harmonic of the radio frequency exciter so marked on the drawings.

The "Thyrite" bank 200 and tap 202 are used to supply screen grid voltage for the tubes of the transmitter. Although the "Thyrite" bank 200 is in series with resistors 32 and 204 in some cases it will be found desirable to connect this bank directly across a rectifier source. Taps to the "Thyrite" bank may then be used to supply voltages of the same or different values to the various screen grids, plates, etc., in which case the "Thyrite" bank 200 will act as a "Thyrite" potentiometer. Such a "Thyrite" potentiometer, when connected across the output terminals of a rectifier, may be used to supply either positive bias as already described or, the positive terminal may be grounded, in which case the taps to the potentiometer may be used to supply negative bias to various grids of the tubes.

I have found that a "Thyrite" bank when used as a potentiometer across a rectifier improves the voltage regulation or constancy of the rectifier, particularly when variable load currents are drawn from taps along the potentiometer. As heretofore used, ordinary resistors across a rectifier require a greater waste of power than that required by the "Thyrite" to obtain the same degree of voltage constancy or regulation. A further advantage in using a "Thyrite" potentiometer across a rectifier resides in the fact that greater smoothing action is obtained. This will be explained in greater detail by referring to Figure 2.

The "Thyrite" bank, as described in the Uselman patent referred to hereinabove, is connected in series with the smoothing reactor 300 and rectifier 302. The smoothing condenser 304 is connected in shunt to the "Thyrite" bank. Either terminal 306 or 308 may be grounded. Over any one of the fins taps t may be taken to supply positive bias in the event that terminal 308 is grounded or a negative bias in the event that terminal 306 is grounded. The choke or filter reactor 300 serves to prevent rapid changes in current flow from the rectifier. This arrangement may be used with a grid biasing rectifier, if desired. In such an arrangement considerable power will be saved as the potentiometer losses are usually determined by the constancy of potential required when variable currents are taken from the taps. When "Thyrite" is substituted for plain resistance in the potentiometer, then the losses may be reduced to 30% of what is necessary in case of a plain resistance potentiometer.

This arrangement for a given current in the potentiometer will be found to give much better regulation or, in other words, a much better regulated voltage at the taps t as compared to a system in which an ordinary resistance potentiometer is used. Likewise, for a given constancy of voltage, much less current may be used in the potentiometer.

Figure 3 is an explanatory graph on a logarithmic scale showing the change in current through a "Thyrite" bank with various changes in voltages impressed.

Referring, now, to Figure 4, which shows a modification of my invention, the first tube 51, which may be of the type known as RCA-833, is in a resonant line controlled oscillator circuit 58. This circuit oscillates continuously both for the marking condition and for the spacing condition. Similar oscillators using resonant

line frequency control are shown and described in U. S. Patents Nos. 2,103,457, 2,095,981, 2,095,980, 2,017,093, 1,988,622 and 1,980,158. Further details are given in a paper published in the Proceedings of the Institute of Radio Engineers, vol. 19, No. 11 for November, 1931, by Conklin, Finch and Hansell; a paper by Hansell and Carter entitled "Frequency control by low power factor line circuits" published in the IRE Proceedings vol. 24, No. 4, April, 1936, and a paper by Hansell entitled "Resonant lines for frequency control" published in Electrical Engineering, a publication of the A. I. E. E., vol. 54, No. 8, August, 1935.

The second tube 52, of the same type as tube 51, in this transmitter is employed in an amplifier circuit 68 into which keying is introduced for producing the telegraph signals. The oscillator 53 and the keyed stage 68 have a common cathode to ground connection through a bank of "Thyrite" resistors 47. The voltage drop through this "Thyrite" produces a part of the working bias on these two tubes. During the spacing interval the keyed stage is cut off so that no current flows from its anode through to the cathode and to ground through this "Thyrite." The oscillator, however, is operating normally and its cathode return current through the "Thyrite" produces a drop of about 500 volts. Grid current in the oscillator grid leak produces additional oscillator bias. The keyed stage obtains its grid voltage from a potentiometer consisting of a 100,000 ohm resistor 54 and the anode-cathode circuit of a keyer tube 53. The keyer tube may be of the type commonly known as RCA-50. The potentiometer is connected between the positive terminal of the rectifier and ground, the resistor being on the positive end. The grid is connected to the mid-point between the resistor and the tube. For the spacing condition the tube 53 is given zero bias. Under this condition equilibrium will be reached when an anode current of 30 mills flows and when the anode voltage is equal to 100 volts. This positive 100 volts is then impressed on the grid of the keyed stage. Since the cathode of the keyed stage is maintained at a voltage of plus 500 its grid is held at negative 400 volts with respect to its cathode. This negative 400 volts is ample to block it even with the excitation voltage superimposed on the grid. For the marking condition the tube 53 is blocked by impressing on its grid a negative voltage. The working bias on the keyed stage is now determined by its grid current which builds up a negative voltage across the resistor 54 of a suitable value to give this stage its working bias voltage. In the marking intervals the keyed stage anode current also flows through the "Thyrite," thus tending to increase the voltage across the "Thyrite." Due to the distinctive characteristics of this "Thyrite" this increase in voltage is not excessive. However, if ordinary resistance were used the system would be unworkable on account of an excessive increase in voltage.

The last stage of this transmitter uses a standard push-pull power amplifier circuit. Tubes 11 and 12 in this circuit may be of the same type as used in the oscillator.

Plate power is supplied by the rectifier 63 using two 872—A rectifier tubes in a single phase, full wave rectifier circuit and is capable of supplying 3000 volts at 1.5 amperes. It will be noted that this rectifier supplies all of the d. c. power required by this transmitter. One of the advantages of using "Thyrite" is that it is practical to

use only one rectifier, thus eliminating a bias rectifier which would otherwise be required.

I claim:

1. In a radio telegraph transmitter having an
5 oscillator circuit and an amplifier stage coupled
thereto, said amplifier stage comprising a ther-
mionic discharge tube having an anode, a cath-
ode and a control grid, means for biasing said
amplifier stage including a resistor connected in
10 a common portion of the anode-cathode and con-
trol grid-cathode circuits, at least a part of said
resistor having a value which varies inversely
with the current flow therethrough and means
for applying an additional bias to said stage com-
prising means for establishing a current flow
15 through said resistor independent of the anode
current of said stage.
2. In a radio telegraph transmitter having an
oscillator circuit and an amplifier stage coupled
20 thereto, said amplifier stage comprising a ther-
mionic discharge tube having an anode, a cathode
and a control grid, means for biasing said ampli-
fier stage including a resistor connected in a com-
mon portion of the anode-cathode and control

grid-cathode circuits, at least a part of said re-
sistor having a value which varies inversely with
the current flow therethrough and means for
applying an additional bias to said stage com-
prising a source of potential connected across
5 said resistor for establishing a predetermined
current flow through said resistor independent of
the anode current of said stage.

3. In a radio telegraph transmitter having an
oscillator circuit and an amplifier stage coupled
10 thereto, said amplifier stage comprising a ther-
mionic discharge tube having an anode, a cath-
ode and a control grid, means for biasing said
amplifier stage including a resistor connected in
a common portion of the anode-cathode and con-
15 trol grid-cathode circuits, at least a part of said
resistor being composed of silicon-carbide where-
by the resistance of said resistor varies inversely
with the current flow therethrough and means
for applying an additional bias to said stage com-
20 prising means for establishing a current flow
through said resistor independent of the anode
current of said stage.

CLARENCE W. HANSELL.