May 21, 1935. J. A. HEANY ET AL 2,002,201

REGENERATIVE SYSTEM AND METHOD OF OPERATING THE SAME

Filed Aug. 25, 1931

Fig. 1

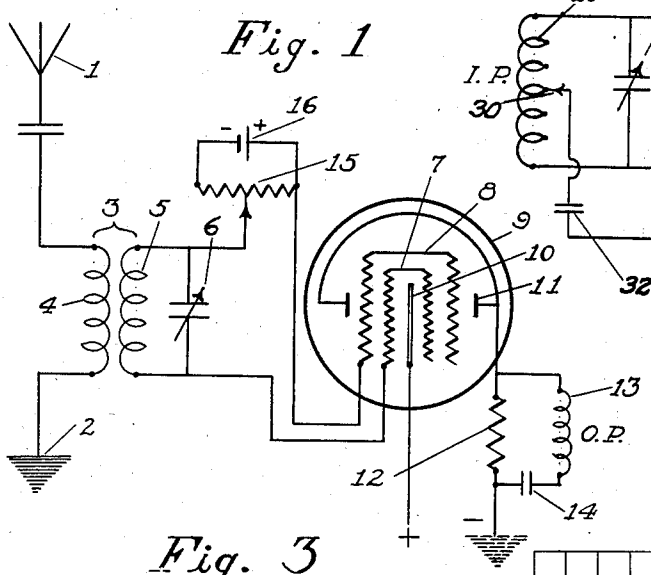


Fig. 4

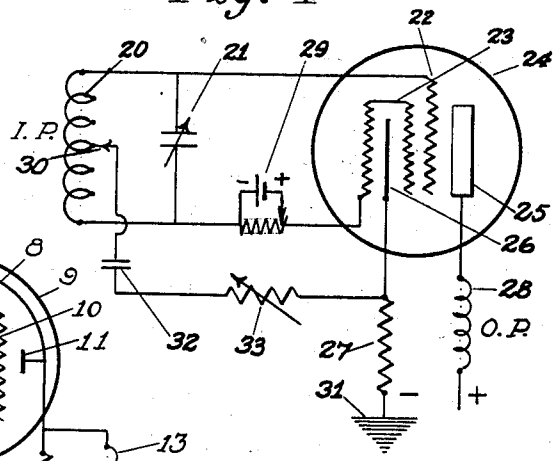


Fig. 2

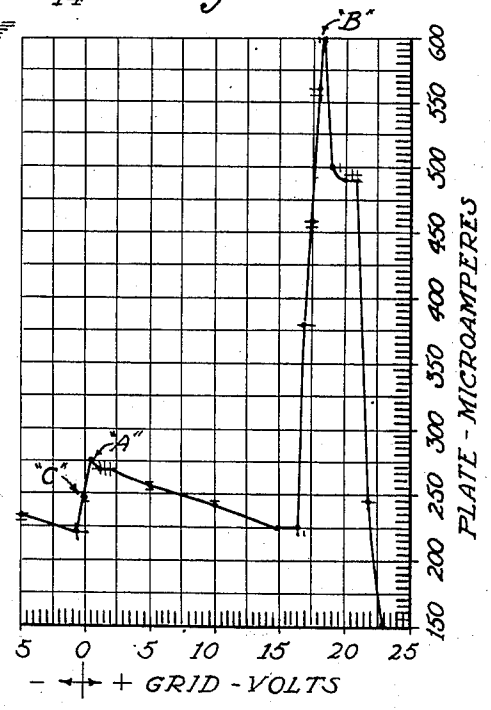
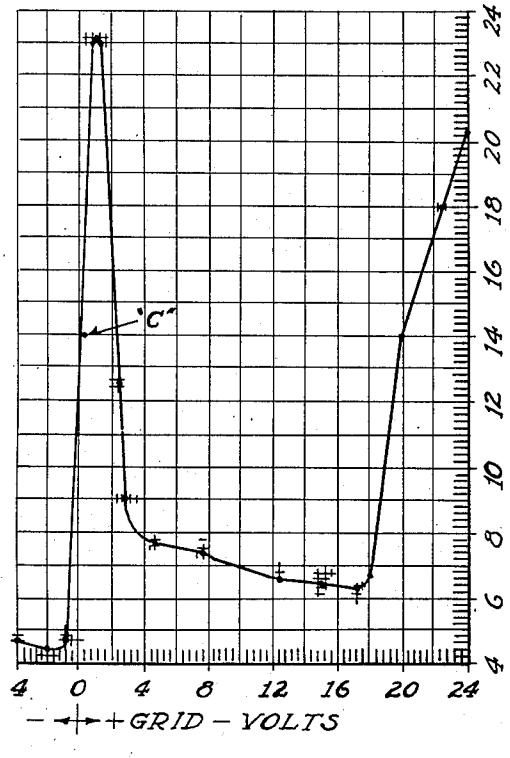


Fig. 3



INVENTORS { John Allen Heany
Herbert St. Laurent

BY Roderick Malcolm

ATTORNEY

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2,002,201

REGENERATIVE SYSTEM AND METHOD OF OPERATING THE SAME

John Allen Heany and Herbert St. Laurent, New Haven, Conn., assignors, by direct and mesne assignments, to Radio Research Laboratories Inc., a corporation of Delaware

Application August 25, 1931, Serial No. 559,214

12 Claims. (Cl. 179—171)

This invention relates to electrical systems for the communication of intelligence, and methods of operating the same, particularly to so-called regenerative systems, and has special reference to the provision of methods and means in connection with tubes or cells of the type disclosed in co-pending applications of John Allen Heany and Philip M. Haffcke, Serial No. 542,304, filed June 5, 1931, and Serial No. 548,410, filed July 2, 1931, whereby the strength of incoming signals is increased within the same tube.

It is well known that if during the reception of a signal the radio frequency component of the output circuit of an electron discharge device can be reimpressed upon the input circuit in synchronism with the incoming signal, the energy of the signal will be amplified.

The fundamental principle upon which regeneration is based is the phenomenon of the reaction between two neighboring electrical circuits, and it is the function of the degree of a coupling between them.

The principal coupling methods used for obtaining this reaction, or regeneration, between output and input circuits are:

1. Capacitative couplings, using either the capacity of the tube itself, a separate condenser, or both in combination.

2. Inductive coupling where a coil in the plate circuit and a coil in the tuned grid circuit are inductively coupled.

Although it is possible to adopt, with certain modifications, either of the above mentioned coupling means to circuits including gaseous discharge devices of the referred to type, we have discovered that it is entirely unnecessary to resort to the use of the extra apparatus and circuit connections involved in present known regenerative systems, further, that without such apparatus and connections it is practical to design and construct circuits which are very sensitive to minute variations in the signal energy and which will amplify signals to a degree comparable favorably with the amplification obtainable with regenerative circuits designed upon present day principles.

Considered from a broad aspect, our invention is predicated upon our discovery that it is practical to utilize, in appropriate circuits, a conductive interlinkage of output and input circuits to effect regenerative amplification and/or detection.

Our invention resides further in the positive control of the degree of regeneration obtained by this method of coupling.

In accordance with our invention we have provided methods and means for effecting regenerative amplification based upon conductive coupling rather than inductive or capacitive coupling, as commonly used in the thermionic art. The conductive coupling between circuits utilized in our invention is preferably "internal" coupling, that is, we may utilize the coupling between circuits resulting from the conductive interlinkage of output and input electrodes inherent in gaseous discharge devices.

Certain objects and principles of our invention will be apparent, and the invention will be more readily understood by reference to the accompanying drawing, in which certain particular preferred forms of the invention are shown by way of illustration, but without limiting the invention thereto.

Fig. 1 shows a radio receiver embodying my invention.

Fig. 2 is a graph of a discharge device operable with, or without, the grid battery of Fig. 1.

Fig. 3 is a graph of a Heany-Haffcke gas cell of a type operable at a small positive bias.

Fig. 4 is a second embodiment of our invention and discloses means for controlling regeneration obtainable with our circuit arrangement.

Figs. 1 and 4 omit illustrations of other stages, and the couplings between stages, the omission being in the interest of simplicity, it being understood the invention is applicable to hook-ups having any desired number of stages. Our invention is intended for use not only in radio circuits, as shown in Fig. 1, but is equally applicable to telephone and telegraph relay circuits, as well as to certain industrial uses.

Referring now in detail to Fig. 1, an antenna 1 is connected to a ground conductor 2, through a coupling transformer 3, having a primary winding 4, and a secondary winding. The terminals of secondary winding 5, which are shunted by a tuning condenser 6, are connected respectively to the electrodes 7 and 8 of a gaseous cell 9. The cell or tube 9 comprises an anode 10 and a cathode element 11, in addition to the input electrodes 7 and 8. A single energizing source is here designated simply by positive pole + and negative pole —. The necessary ground connection, which may be through the transformer of a power pack, or through the coils thereof, is shown symbolically by the broken lines. A ballast resistor 12 serves to limit the maximum amount of direct current permitted to pass through the tube. In the tube here shown either or both cathode 11 and anode 10 may be output electrodes, as will hereinafter more fully appear. In any event, gas

in the tube affords an internal conductive path between all of the electrodes, and it is to be understood that we contemplate the use of tubes or cells of any suitable type wherein there is a conductive path between input and output electrodes. The output coupling from one stage to the next stage may be at any suitable point. It is entirely practical, for instance, to take the output 13 from across the terminal of ballast resistor 12, in which case one leg of the connection should include a condenser 14. A variable non-inductive potentiometer 15 is connected across battery 16 in the input circuit.

The tube 9 is preferably a Heany-Haffcke gas cell of either "the internal cathode type" disclosed in co-pending application, Serial No. 542,304, or of "external cathode type," as here shown, and as disclosed in co-pending application, Serial No. 548,410.

The construction and operation of the Heany-Haffcke gas cell, as disclosed in the applications above cited, may be here briefly described as follows: two electrode elements, for instance, elements 8 and 11 of the present Fig. 1, constitute the working cathode of the cell, that is, these electrodes may be considered as exciters of apparent electronic emission, the gas in the container being the prime source of electrons. One of these electrode elements, for instance element 8, is positive to the cathode element 11, and is negative to the anode 10. This electrode 8, because of its dual relationship, is designated "cathanode." The anode 10 is similar in function to the plate in a thermionic tube, at least it serves to accelerate electrons towards itself, and may be considered as one of the output electrodes. The control electrode or grid is 7.

The position and arrangement of grid 7 and battery 16 are analogous to that of the grid and grid battery in circuits employing thermionic tubes. Our arrangement shown in Fig. 1, should not be confused with so called "biasing" arrangements, known in the art, which are all directed to maintaining the grid at such a negative potential relative to the cathode that substantially no current will flow in the input circuit. In accordance with our arrangement the grid may carry a large percentage of the anode or plate current, and, were it possible to offset by biasing or otherwise this grid current, the tube would be unoperable for our present purpose.

The battery 16 is not, therefor, arranged to prevent current flowing in the grid circuit (in some cases battery 16 actually adds current to the circuit) but serves rather to position the working point of the cell on the proper section of the grid voltage—plate current curve,—all of which will more fully appear in connection with Figs. 2 and 3. The non-inductive potentiometer or variable resistor 15 serves to control the interaction between the conductively coupled output and input circuits, and hence the effective degree of regeneration, by varying the resistivity or conductivity of the conductive coupling.

Fig. 2 shows a plate current-grid voltage curve of a gas cell. In the graph of the particular cell here shown it will be apparent to those skilled in the art that the device may be worked at point C, zero bias, and, therefore, without a battery, or at approximately 15 to 20 volts positive bias, in which case either a battery of that value or an equivalent resistor in the plate circuit is necessary to fix the "working point." Since it will be recalled that amplification depends upon steepness rather than the height of the plate-current grid voltage curve, and that it appears that "hump" A approximates "hump" B in steepness, it is obvious that our system for controlling regeneration is independent of so called "biasing" arrangements, as it is operable without any "bias," if so desired."

Fig. 3 is a graph of a Heany-Haffcke gas cell of the "external cathode" type. The graph is plotted to plate current as ordinates and grid voltage as abscissæ—the calibration in milliamperes and volts respectively. The "working point" C, on the plate current-grid voltage curve is preferably at approximately .2 volts positive. With this particular tube we may include in our circuit the grid battery described in connection with Fig. 1, it being understood from what has gone before that while for gas tubes having certain characteristics we may employ a biasing battery, or its equivalent, it is not always necessary that we do so.

In Fig. 4 20 is the secondary of an input circuit transformer, 21 a tuning condenser; the circuit 20—21 constitutes the tuned circuit, to which the "feed-back" from plate 25 is directed. The conductive path from plate 25 to tuned circuit 20—21 is through the gas, which has been rendered conductive by ionization, to grid 22 and through the grid lead to circuit 20—21. The cell 24 here illustrated may be an "internal cathode" gas discharge device of the type previously described, in which case cathode 26 and cathanode 23 comprise the ionizing circuit; electrodes 22 and 23, corresponding to electrodes 7 and 8 in Fig. 1, are terminals for the input circuit.

The output coupling may be in the plate or anode circuit, and is diagrammatically represented at 28. The maximum amount of direct current permitted to pass through the tube from the single source of supply (represented by positive and negative symbols) is limited by ballast resistor 17. In the embodiment here shown the grid biasing battery is designated 29 and it may be utilized, if necessary or desirable, to fix the working point on the grid voltage-plate current curve.

Instead of the potentiometer in the grid lead as described in connection with Fig. 1, we may have the regeneration control directly in the tuned circuit 20—21. Thus, a variable connection 30 is in electrical association with secondary 20 and ground 31 through condenser 32 and variable resistor 33. By proper adjustment of variables 30 and 33 any desired value or amount of current may be reimpressed on tuned input circuit 20—21.

One very real advantage of utilizing the conductive connection made practical by our invention, and one which will be obvious to those skilled in the art, is this: regeneration is independent of frequency. In present non-regenerative circuits employing inductive or capacitive feed-back the "tickler" or other control must be varied for different frequencies; with our invention the controls may be set for any desired value, and need not be changed regardless of the frequency of the incoming signal.

As many further modifications and changes in details will suggest themselves to those skilled in the art, without departing from the spirit and scope of our invention, it is to be understood that the foregoing is to be interpreted as illustrative, and not in a limiting sense, except as required by the appended claims, and by the prior art.

What is claimed is:

1. A regenerative system comprising cathanode,

cathode grid and anode electrodes immersed in a conductive gaseous medium, input and output circuits for said electrodes, said input circuit comprising a conductive connection from the grid to the cathanode, and said output circuit comprising a conductive connection from the anode to the cathode whereby energy in the output circuit is fed back conductively through the gas filling to the input circuit, and means to provide a positive control for varying the amount of regeneration.

2. A regenerative system comprising cathanode, cathode grid and anode electrodes immersed in a conductive gaseous medium, input and output circuits for said electrodes, said input circuit comprising a conductive connection from the grid to the cathanode, and said output circuit comprising a conductive connection from the anode to the cathode, whereby energy in the output circuit is fed back conductively through the gas filling to the input circuit, and means connected to the input circuit to provide a positive control for varying the amount of regeneration.

3. A regenerative system comprising a gas filled electric discharge device having on the interior thereof input and output electrodes, an input circuit conductively connecting the input electrodes together exteriorly of the device, an output circuit conductively connecting the output electrodes together exteriorly of the device, and variable means in said input circuit to provide a positive control over the amount of regeneration.

4. A system according to claim 3 in which means for controlling the regeneration is serially connected in the input circuit.

5. A regenerative system comprising an electric discharge device having a gas filling, input and output electrodes within said device, input and output circuits conductively connecting said electrodes together externally of the device, and a variable impedance in the input circuit for positively controlling the amount of energy fed back from the output circuit to the input circuit.

6. A system according to claim 5, in which the said impedance comprises substantially entirely a resistance.

7. A regenerative system comprising a gas filled electric discharge device, a cathode, a cath-anode, control grid and anode within said device, a tuned input circuit connected across the cathanode and grid, an output circuit connecting the anode and cathode and means in said input circuit for controlling the amount of energy fed back thereto from the output circuit due to the gas filling.

8. A system according to claim 7 in which the means for controlling the amount of energy fed back comprises a variable impedance connecting the tuned circuit to ground.

9. A regenerative system comprising a gas filled electric discharge device, cathode, cathanode, control grid and anode electrodes within said device, a tuned input circuit connected across the cathanode and control grid, an output circuit connected across the cathode and anode, and a potentiometer arrangement in said tuned circuit for controlling the amount of regeneration and for biasing the grid to the proper point of the grid voltage-plate current characteristic.

10. A regenerative system comprising a gas filled electric discharge device, cathode, cathanode, control grid and anode electrodes within said device, a tuned input circuit connected across the grid and cathanode, an output circuit connected across the cathode and anode, a source of steady potential connected across the cathode and anode, and a regeneration control path comprising a variable impedance connection from a point in the tuned circuit to one terminal of said source of potential.

11. A regenerative system comprising a gas filled electric discharge device, cathode, cathanode, control grid and anode electrodes within said device, a tuned input circuit connected across the control grid and cathanode, an output circuit including a source of steady working potential connected across the cathode and anode, a regeneration control path having one end connected to a terminal of said source of potential, the other end being adjustably connected to the said tuned circuit and including a variable resistance.

12. A regenerative system comprising a gas filled electric discharge device, cathode, cathanode, control grid and anode electrodes within said device, a tuning inductance having one terminal connected to the cathanode, a circuit including a source of steady working potential connected across the cathode and anode, and a variable impedance connection extending from a point intermediate the ends of the inductance to one terminal of said source of potential for controlling the amount of regeneration.

JOHN ALLEN HEANY.
HERBERT ST. LAURENT.