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GAIN CONTROL CIRCUITS

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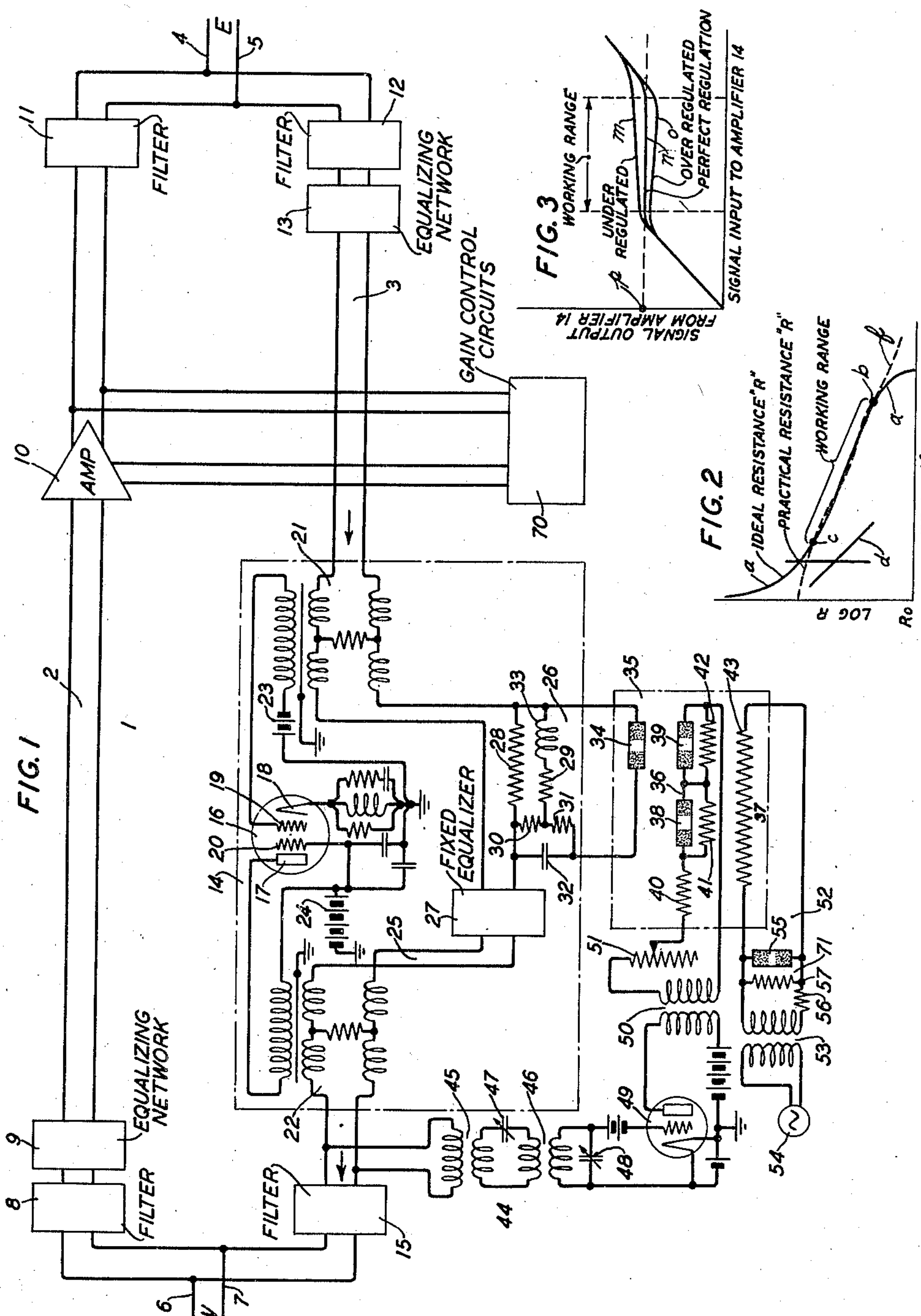

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GAIN CONTROL CIRCUITS

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16 Claims. (Cl. 178—44)

This invention relates to gain control circuits for signal transmission lines and particularly to gain control circuits controlled by pilot currents on the transmission lines.

One object of the invention is to provide gain control circuits for a transmission line having a resistance element with a high temperature coefficient of resistance for controlling a repeater amplifier that shall continuously control the resistance element in an improved manner to maintain the attenuation of the transmission line constant.

Another object of the invention is to provide gain control circuits for a transmission line having a resistance element with a high temperature coefficient of resistance in an oven for controlling a repeater amplifier that shall control the oven temperature according to the energy level of the currents on the transmission line beyond the amplifier and that shall compensate the oven temperature for changes in the room temperature.

A further object of the invention is to provide gain control circuits for a transmission line having a resistance element of silver sulphide in an oven for controlling a repeater amplifier that shall control the oven temperature according to the energy level of a pilot current on the transmission line to hold the line attenuation constant and that shall control the oven temperature according to the room temperature to compensate the oven temperature for changes in the room temperature.

The attenuation of a long signal transmission line varies with changes in the weather and changes in temperature. In order to effect good quality of signal transmission it is necessary to hold the attenuation of a signal transmission line substantially constant. The attenuation of a transmission line may be controlled either by controlling an attenuation network on the line or by controlling a repeated amplifier on the line.

The invention has been illustrated by means of a carrier current telephone system employing one range of carrier currents for transmitting signals in one direction and another range of carrier currents for transmitting signals in an opposite direction. A pilot current is employed with each range of carrier currents for gain control purposes. At repeater stations the east-to-west currents are separated from the west-to-east currents by means of directional filters. The repeater amplifiers in the transmission paths at a repeater station are provided with feed-back circuits which are controlled to maintain the attenuation in each transmission path substantially constant.

According to the invention a resistance element having a high temperature coefficient of resistance is included in an attenuation network. The attenuation network is included in the feedback circuit of a repeater amplifier. The resistance element is preferably composed of silver sulphide but may be composed of barium, zinc oxide or any other suitable material having a high temperature coefficient of resistance if so desired. An oven or enclosure which encloses the element of silver sulphide also encloses two heaters so that the silver sulphide and the two heaters are substantially at the same temperature. One of the heaters controls the oven temperature according to the energy level of the pilot current on the transmission path beyond the repeater amplifier. The second heater is energized according to changes in the room temperature to compensate the oven temperature for changes in the room temperature. The oven or enclosure may be omitted if the silver sulphide and two heaters are in close proximity to each other.

The first heater comprises resistance elements having different temperature coefficients of resistance which are connected in series and parallel circuit relation. This heater may be composed of silver sulphide elements having a high negative temperature coefficient of resistance and resistance elements of iron which have small resistance variations for the temperatures employed. The elements comprising the heater are designed so that the heater will have a predetermined temperature resistance characteristic for controlling the silver sulphide element in the attenuation network to maintain the attenuation of the transmission path constant. A variable resistance element connected in series with the first heater and located outside the oven may be adjusted to effect under regulation, perfect regulation or over regulation. A filter which selects the pilot current on the transmission path is connected to the path beyond the repeater amplifier therein. The output from the filter is amplified and supplied to the first heater for controlling the oven temperature.

The second heater which may be composed of any suitable resistance material having substantially no resistance variation for the temperatures employed is connected to a suitable energizing circuit outside the oven. In the energizing circuit are connected resistance elements having different temperature coefficients of resistance. The resistance elements in the energizing circuit outside the oven may be composed of silver sulphide and iron and are subject to room temperature. The energizing circuit for the second heater is preferably connected to a source of alternating current.

In the accompanying drawing, Fig. 1 is a diagrammatic view of gain control circuits constructed in accordance with the invention;

Fig. 2 is a set of curves illustrating the resistance temperature characteristic of the control heater shown in Fig. 1; and

Fig. 3 is a set of curves showing how the output level is regulated.

Referring to Fig. 1 of the drawing, a repeater station having a west-to-east channel or path **2**, and an east-to-west path **3** is shown on a transmission line comprising east conductors **4** and **5** and west conductors **6** and **7**. The west-to-east channel **2** comprises a directional filter **8**, an equalizing network **9**, a repeater amplifier **10** which is preferably of the thermionic type, and a directional filter **11**. The directional filters **8** and **11** select the carrier currents which are employed to transmit signals from the west to the east. The directional filters **8** and **11** also select the pilot current employed to control the gain of the carrier currents employed for transmitting signals from the west to the east.

The east-to-west channel or path **3** comprises a directional filter **12**, an equalizing network **13**, a repeater amplifier **14**, and a directional filter **15**. The directional filters **12** and **15** select the carrier currents employed to transmit signals from the east to the west. The directional filters **12** and **15** also select the pilot current employed for controlling the amplifier **14**. Inasmuch as the two channels **2** and **3** operate in a similar manner, a detailed description will be given only of the control of the channel **3** for maintaining the line attenuation constant.

The repeater amplifier **14** comprises a space discharge device **16** having an anode **17**, a cathode **18**, a grid **19** and a screen grid **20**. The input circuit for the space discharge device **16** is connected to the channel **3** by means of a hybrid coil network **21**. The output circuit for the device **16** is connected to the channel **3** by means of a hybrid coil network **22**. A biasing battery **23** is provided for the grid **19** and battery **24** is provided for the anode **17**.

A feedback circuit **25** for controlling the space discharge device **16** is connected between the hybrid coil network **21** and the hybrid coil network **22**. The feedback circuit comprises a regulating network **26** and a fixed equalizer **27**. The regulating network **26** is controlled in a manner to be hereinafter set forth for controlling the feedback on the amplifier **16** to maintain a transmission line attenuation on the path **3** substantially constant. A repeater amplifier of the type above described is disclosed in the patent to H. S. Black, No. 2,102,671, December 21, 1937. Reference may be had to this application for a more detailed description of the operation of the amplifier.

The regulating network **26** comprises resistance elements **28**, **29**, **30** and **31**, a capacity **32**, an inductance **33**, and a resistance element **34** having a high temperature coefficient of resistance. Preferably the resistance element **34** is composed of silver sulphide. It is to be understood that the resistance element **34** may be composed of other materials, such as barium or zinc oxide if so desired. The element of silver sulphide **34** is positioned inside an oven or enclosure **35**. The oven **35** also encloses two heaters **36** and **37**. The heater **36** is energized according to the energy level of the pilot current on the channel **3** beyond the repeater amplifier **16**. The heater **37** is energized according to variations in room temperature to compensate the oven temperature for changes in room temperature. The heater **36** comprises two elements **38** and **39** having high temperature coefficients of resistance and three resistance elements **40**, **41** and **42**, which have a different temperature coefficient of resistance. Preferably the elements **38** and **39** are composed of silver sulphide. The elements **40**, **41** and **42** may be composed of iron resistance and should have little change in resistance for the temperature range employed in the oven. The heater **37** comprises the resistance element **43** which has a substantially constant resistance within the working range of temperatures employed in the oven.

A filter **44** comprising two transformers **45** and **46** and two adjustable condensers **47** and **48** is connected to the channel **3** beyond the repeater amplifier **16** for selecting the pilot current on the channel **3**. The filter **44** is connected to the input circuit of a space discharge amplifier **49**. The output circuit of the amplifier device **49** is connected by a transformer **50** to an energizing circuit for the heater **36**. An adjustable resistance element **51** is included in the energizing circuit for the heater **36**. The resistance element **51** is positioned outside the oven **35** for determining whether the regulation effected by the silver sulphide element **34** will be over regulation, perfect regulation, or under regulation, as the level coming in from line **4**, **5** rises and falls due to weather change.

An energizing circuit **52** for the heater **37** is connected by a transformer **53** to a source of alternating current **54**. A resistance network **71** is connected in the energizing circuit **52** for controlling the energization of the heater **37** according to changes in the room temperature. The network **71** comprises an element **55** of silver sulphide having a high temperature coefficient of resistance and two resistance elements **56** and **57**, which may be common iron resistance. The network **71** is adjusted so that the heater **37** compensates for the loss in temperature from the oven **35** effected by changes in room temperature.

In the circuit employed to describe the invention, the oven **35** has a working temperature range between 120° and 350° Fahrenheit. When working the oven **35** within the above-mentioned temperature range approximately all loss of heat from the oven will be by conduction. Radiation of heat from the oven is negligible. The rate of heat loss will then be closely proportional to the difference in temperature between the oven and the room.

Let:

T°=room temperature.

$t°$ =temperature within the oven.

h =heat given off by heater **36** per second.

H =heat which escapes from oven into the room per second.

k =heat loss constant (from oven to room).

h' =heat put into oven by heater **37** per second.

R =resistance of heater **36** which is a function of $t°$.

R_0=resistance **51** plus the plate resistance of the tube **49** as seen through transformer **50**.

e_3 =potential supplied by transformer **50** which is proportional to the pilot level put out by amplifier **14**.

Then, when the temperature of the oven **35** has reached a stable state;

$$H=h+h' \qquad (1)$$

$$H=k(t°-T°) \qquad (2)$$

The above Equation 2 may be written as follows:

$$H=k[(t°-120°)+(120°-T°)] \qquad (3)$$

In Equation 3 it is apparent that we can make

$$h=k(t°-120°) \text{ and } h'=k(120°-T°) \qquad (4)$$

This makes h a function of oven temperature only and h' a function of room temperature only.

$$h=\frac{(e_3)^2}{(R_0+R)^2}R=k(t°-120°) \qquad (5)$$

$$\frac{e_3^2}{R_0^2+2R_0R+R^2}R=k(t°-120°) \qquad (6)$$

From Equation 6 the value of an ideal resistance R as a function of the temperature $t°$ can be determined in terms of e_3, R_0 and k, which are known parameters.

Referring to Fig. 2 of the drawing, the curve a having the abscissae in terms of $t°$, the temperature within the oven, and the ordinates in terms of resistance on a logarithmic scale represents the ideal resistance R for the heater **36**. The curve f represents a practical design. The working range for which a practical R can be designed would be between the points b and c on the curve a where the practical resistance closely coincides with the ideal. The curve d shows the resistance R for the heater if formed of silver sulphide alone.

In the above equations it has been assumed that the room temperature is constant at 120° for convenience in explaining the operation of the regulator. The changes in room temperature which may take place are compensated for by means of the heater **37**. The curve a in Fig. 2 of the drawing shows the resistance temperature characteristic which the heater **36** must have to maintain the attenuation on the east-to-west channel of the transmission line constant. The heater **36** as before set forth is composed of resistance elements having different temperature coefficients of resistance so combined as to approximate the ideal over the working range b to c in Fig. 2.

If the input energy level of the pilot current on the channel **3** tends to rise above normal, the voltage e_3 which is supplied by the transformer **50** to the energizing circuit for the heater **36** is raised. The temperature of the heater **36** is raised for controlling the silver sulphide element **34**. The temperature resistance characteristic of the heater **36** follows the curve a shown in Fig. 2 of the drawing. The increase in temperature lowers the resistance of the silver sulphide element **34**. The lowering of the resistance of the element **34** lowers the impedance of the network **26** in the feedback circuit **25**. This causes an increased feedback to lower the gain of amplifier **14**, and therefore lower the energy level of the currents put out on the channel **3**.

In case the energy level of the pilot current on the channel **3** beyond the amplifier **16** is lowered below normal level, then the potential supplied by the transformer **50** is reduced. This causes a reduction in the heat supplied by the heater **36** to the silver sulphide element **34**. A reduction in the temperature of the silver sulphide element **34** increases the resistance of the controlling network **26** to lower the negative feedback on the amplifier **16**. By such means the energy level of the signal currents on the channel **3** is raised.

The adjustable resistance **51** in the energizing circuit is one means for adjusting R_0 to obtain the desired regulating characteristic for the amplifier **14**. When R_0 is made just the right value the regulator will always bring the input level from amplifier **14** back to the same constant level p in Fig. 3 each time the input level to amplifier **14** is changed up or down; that is, we get perfect regulation as shown by curve n in Fig. 3. When R_0 is made larger than this value the regulator will not bring the output level all the way back to its original level when the input level is changed up or down; that is, we get under regulation as shown in curve m. On the other hand, when R_0 is made smaller than this value the regulator will over regulate; that is, a higher input level to amplifier **14** will bring about a lower output level and vice versa as shown in curve o. The amount of under regulation or over regulation desired may be adjusted by adjusting R_0. It is obvious that other means than resistance **51** may be used to vary R_0 such for instance as taps on transformer **50**.

The resistance network **71** in the energizing circuit for the heater **37** is subjected to room temperature changes and controls the heater **37** in accordance with changes in the room temperature. The resistance elements having different temperature coefficients of resistance are varied to insure compensating the oven temperature for variation in the room temperature.

The channel **2** operates in exactly the same manner as described above with respect to channel **3**. Gain control circuits **70** are provided for controlling the repeater amplifier **10** in the same manner as the repeater amplifier in channel **3** is controlled.

Modifications in the circuits and in the arrangement and location of parts may be made within the spirit and scope of the invention and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a regulator for controlling a characteristic of a circuit, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling said characteristic of the circuit, a heater in said oven having a regulating characteristic and comprising resistance elements arranged in series and parallel circuit relation, the resistance elements of said heater having different rates of resistance variations with temperature changes for obtaining a complex heater that varies in resist-

ance with temperature changes to effect a regulating operation and means controlled according to the characteristic of said circuit for energizing said heater to heat said control element according to the heater characteristic and maintain the circuit characteristic constant with precision.

2. In a regulator for controlling a characteristic of a circuit, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling said characteristic of the circuit, means comprising a heater in said oven to control the temperature of said element, according to changes in said characteristic, a second heater in said oven, a source of energy in an energizing circuit for said second heater, and means comprising resistance elements subjected to room temperature, having different temperature coefficients of resistance and inserted in said energizing circuit to compensate the oven temperature for changes in the room temperature.

3. In a gain control circuit for a signal transmission line, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling the transmission line attenuation, a heater for said control element in said oven comprising resistance elements arranged in series parallel circuit relation and having different temperature coefficients of resistance for controlling said element, means for energizing said heater according to the energy level of the signals on the transmission line and means for compensating the oven temperature for changes in the room temperature.

4. In a gain control circuit for a signal transmission line, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling the transmission line attenuation, a heater in said oven comprising resistance elements arranged in series and parallel circuit relation and having different temperature coefficients of resistance for controlling said element to maintain the line attenuation constant, means for energizing said heater according to the energy level of the signals on the transmission line, a second heater in said oven, and means for energizing said second heater to compensate the oven temperature for changes in room temperature.

5. In a gain control circuit for a signal transmission line, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling the transmission line attenuation, a heater in said oven for said control element comprising resistance elements arranged in series and parallel circuit relation and having different temperature coefficients of resistance, means for controlling said heater according to the line attenuation, a second heater in said oven, and means controlling said second heater comprising a source of energy and resistance elements subjected to room temperature and having different temperature coefficients of resistance to compensate the oven temperature for changes in the room temperature.

6. In gain control circuits for a signal transmission line, an oven, means comprising a control element in said oven having a high temperature coefficient of resistance for controlling the transmission line attenuation, a heater in said oven comprising resistance elements arranged in series and parallel circuit relation and having different temperature coefficients of resistance for producing a temperature resistance characteristic of a predetermined character, a variable resistance in the energizing circuit of said heater to selectively effect flat gain, raising gain and lowering gain by the control circuits, and means for controlling said heater according to the energy level of the signals on the transmission line.

7. In gain control circuits for a signal transmission line, an oven, a control element of silver sulphide in said oven, means for controlling the transmission line attenuation according to the temperature of the element, a heater in said oven comprising elements of silver sulphide connected in series and shunt circuit relation to resistance elements having a different temperature coefficient of resistance, means for energizing said heater according to the energy level of the signals on the transmission line to govern said control element of silver sulphide and maintain the line attenuation constant, a second heater in said oven, a source of current in an energizing circuit for said second heater and means comprising resistance elements in said energizing circuit for controlling said second heater to compensate the oven temperature for changes in room temperature, said last-mentioned resistance elements having different temperature coefficients of resistance and are subjected to room temperature.

8. In gain control circuits for maintaining the attenuation on a transmission line constant, an oven, an element of silver sulphide in said oven for controlling the line attenuation according to the temperature thereof, a heater in said oven comprising resistance elements having different temperature coefficients of resistance, means for energizing said heater according to the energy level of the signals on the transmission line to control the temperature of said silver sulphide and maintain the line attenuation constant, a second heater in said oven, and means comprising a source of current and a resistance arrangement subjected to room temperature for controlling the energization of said second heater to compensate the oven temperature for changes in the room temperature.

9. In combination, a transmission line carrying signal currents, an oven enclosing a resistance element having a high temperature coefficient of resistance, means controlled by said resistance element for controlling the attenuation of the transmission line, a heater in said oven for controlling said resistance element, means for energizing said heater according to the energy level of the currents on said line, a second heater in said oven, and means for energizing said second heater to compensate the oven temperature for changes in the room temperature.

10. In combination, a transmission line carrying signal currents, an oven, a resistance element in said oven having a high temperature coefficient of resistance for controlling the attenuation of said line at a predetermined control point, a heater in said oven for controlling the temperature of said resistance element, means for energizing said heater according to the energy level of the signal currents beyond said control point to maintain the line attenuation constant, a second heater in the oven, and means for energizing said second heater to compensate the oven temperature for changes in the room temperature.

11. In combination, a transmission line carrying signal currents and pilot current, an oven, means comprising a resistance element of silver sulphide in said oven for controlling the attenuation of said line at a predetermined control

point, a heater in said oven for controlling the temperature of said element of silver sulphide, means for energizing said heater according to the energy level of the pilot current beyond said control point to maintain the line attenuation constant, a second heater in the oven, and means for energizing said second heater to compensate the oven temperature for changes in the room temperature.

12. In combination, a transmission line carrying signal currents and having a repeater amplifier therein, a feedback circuit for effecting control of said amplifier, an attenuation network comprising a resistance element having a high temperature coefficient of resistance in said feedback circuit, an oven enclosing said resistance element, a heater having a regulating characteristic for said resistance element included in said oven, said heater changing in resistance with temperature changes for effecting a regulating operation, and means for continuously operating said heater according to the energy level of the signals on the transmission line to control said resistance element in accordance with the heater characteristic and maintain the energy level of the signal current beyond said amplifier constant.

13. In combination, a transmission line carrying signal currents and a pilot current, a repeater ampliler on said line, a feedback circuit for controlling said amplifier, an attenuation network in said feedback circuit comprising a resistance element having a high temperature coefficient of resistance, an oven enclosing said resistance element, a heater having a regulating characteristic and included in said oven for heating said resistance element, said heater changing in resistance with temperature changes for effecting a regulating operation, means comprising a filter for selecting said pilot current from the line beyond said amplifier, and means governed by the output from said filter for continuously energizing said heater to heat said resistance element according to the heater characteristic and maintain the energy level of the signal currents beyond said amplifier constant.

14. In combination, a transmission line carrying signal currents and a pilot current, a repeater amplifier on said line, a feedback circuit for controlling said amplifier, an attenuation network in said feedback circuit comprising an element of silver sulphide, an oven enclosing said element of silver sulphide, a heater included in said oven for heating said element of silver sulphide, means governed by the energy level of the pilot current on the line beyond said amplifier for continuously energizing said heater to maintain the energy level of the signal current beyond said amplifier constant, a second heater in said oven, and means for energizing said second heater to compensate for changes in the room temperature.

15. In a regulator for controlling the characteristic of a circuit, means comprising a control element having a high temperature coefficient of resistance for controlling said characteristic of the circuit, a heater in close proximity to said control element and having a regulating characteristic, said heater comprising resistance elements arranged in series and parallel circuit relation and having different rates of resistance variations with temperature changes for obtaining a complex heater that varies in resistance with temperature changes to effect a regulating operation and means controlled according to the characteristic of said circuit for energizing said heater.

16. In a regulator for controlling a characteristic of a circuit, means comprising a control element having a high temperature coefficient of resistance for controlling said characteristic of the circuit, means comprising a heater in close proximity to said control element to control the temperature of the element according to changes in said characteristic, a second heater in close proximity to said control element, a source of energy in an energizing circuit for said second heater, and means comprising resistance elements subjected to room temperature, having different temperature coefficients of resistance and inserted in said energizing circuit to compensate for changes in the room temperature.

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