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TRANSMISSION REGULATION

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FIG. 1

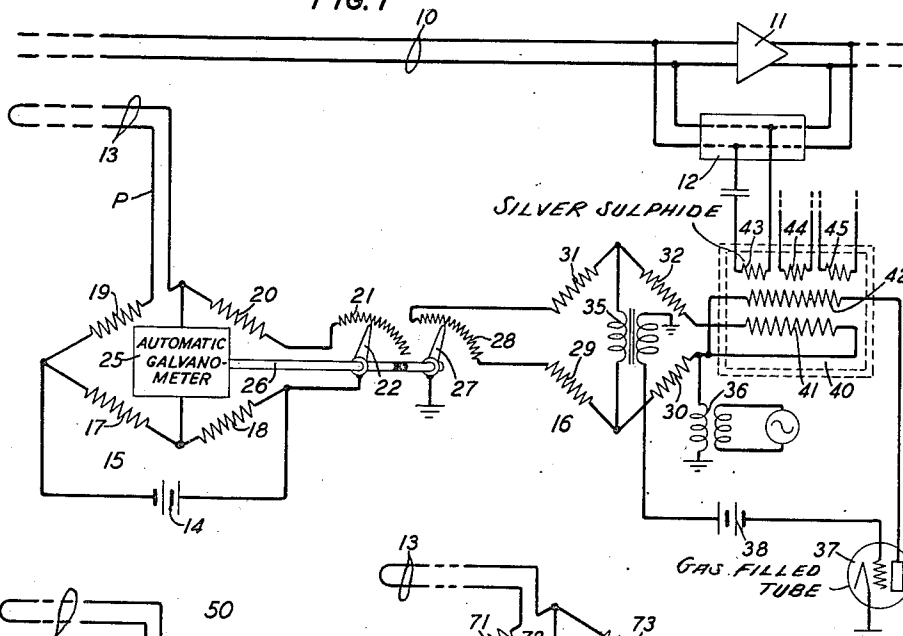


FIG. 3

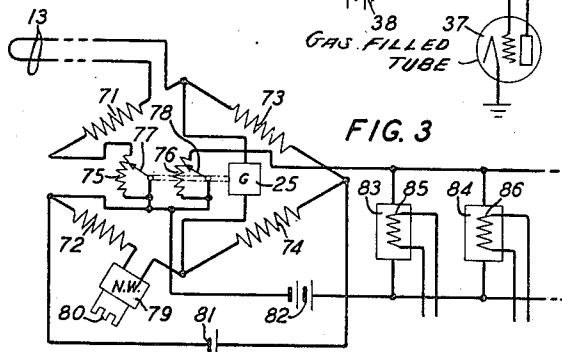
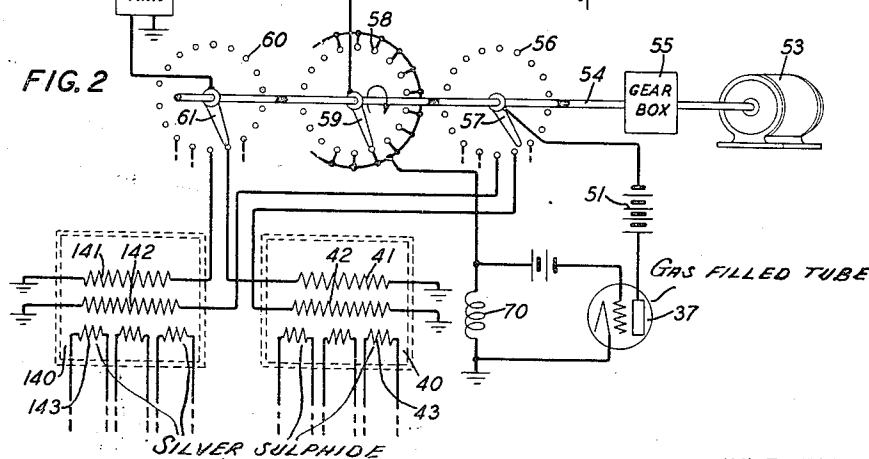


FIG. 2



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TRANSMISSION REGULATION

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9 Claims. (Cl. 178—44)

The present invention relates to the control of transmission over a line or through a system and has particular application to signalling systems such as long telephone lines in which the transmission characteristic is subject to change with climatic or temperature variations.

The general object of the invention is to effect compensation for variations in transmission or to control transmission or gain in a simple and economical manner and with accuracy.

A feature of the invention is the use of a thermo-sensitive element for controlling gain or transmission, in combination with simple circuit means for controlling the temperature of the thermo-sensitive element. As one means for controlling the temperature of this element a gas-filled tube may be employed to control the current used to heat the element. The gas tube or other current control means is in turn controlled by a means associated with the line or circuit to detect the changes to be compensated. This detecting means may in some cases advantageously include a device for correcting the compensating mechanism for changes in ambient or room temperature. Switching apparatus may be provided for enabling one control mechanism to serve for a large number of temperature-controlling devices in rotation whereby a large number of lines or amplifiers may be kept in proper adjustment.

These and other features of the invention, as well as its nature and objects, will be made more clear in the following detailed description of illustrative embodiments as shown in the accompanying drawing.

In the drawing, Fig. 1 is a schematic circuit diagram of one form of embodiment of the invention in an automatic regulator for a group of repeaters;

Fig. 2 shows a modification in which the same regulating apparatus is in part common to several groups of repeaters with a separate heater for each group; and

Fig. 3 shows a simplified control system incorporating a room-temperature compensating device.

In Fig. 1 the line 10 is assumed to be one of a number of similar lines that may preferably be enclosed by a lead sheath to make up a cable of standard construction. Each line, such as 10, is assumed to include a repeater 11 at intervals along the line. In the case of voice current lines these repeaters may be spaced in the order of fifty miles apart, while if the lines transmit high frequency carrier waves such as used in multiplex carrier telephony, the spacing may be much shorter, for example, ten miles. The re-

peater 11 is assumed to be of the stabilized feed-back type having a feed-back path 12, from its output to its input for feeding back waves in such manner as to reduce the gain of the repeater 11 and thereby increase its stability and improve its linearity in accordance with the invention of H. S. Black disclosed and claimed in application Serial No. 606,871, filed April 22, 1932. While this type of repeater is preferred, it is to be understood that any suitable type of amplifier may be used at 11 with suitable provisions for changing its gain under control of the regulating apparatus presently to be described.

Enclosed in the same sheath with the lines, such as 10, is a special conductor 13 extending the length of one repeater section and used as a pilot conductor to enable a measurement to be made at the repeater station of the changes in resistance of the cable with changes in temperature. This pilot conductor 13 controls the operation of the regulating mechanism which comprises in part two bridges 15 and 16.

The bridge 15 comprises ratio arms 17 and 18, a third arm including the pilot conductor and preferably some added resistance 19 and a fourth or variable arm including resistance 20 and variable resistance 21. Battery 14 furnishes the necessary current for the bridge 15.

Associated with the bridge 15 is an automatic galvanometer 25 of a type known in the art including a source of mechanical power for moving the shaft 26 through an angle proportional to the angle of deflection of the galvanometer due to an unbalanced condition of the bridge. Such instruments are available on the market and it is not thought necessary to illustrate the mechanism in detail. One example of an automatically balancing galvanometer mechanism suitable for use at 25 is given in U. S. patent to Ulrich 1,647,383, November 1, 1927. Rotation of the shaft 26 moves arms 22 and 27 over resistors 21 and 23 for a purpose presently to be described.

Bridge 16 comprises fixed arms 29, 30, 31 and 32 with a portion of each arm 29 and 31 variable depending upon the position of switch arm 27 on resistance 28. Arm 32 of the bridge includes the thermo-sensitive element 41 enclosed in the heating chamber 40. Alternating current power for the bridge 16 is furnished from a suitable source 36, which, it will be observed, is also in the anode circuit of gas-filled tube 37 in series with heater resistance 42 inside heat chamber 40. The grid of this tube is connected through suitable bias battery 38, effectively in the diagonal

of the bridge 16 through the coupling transformer 35. This transformer 35 steps up the voltage making the bridge control more sensitive. It also avoids grounding the bridge diagonal with which the grid circuit of tube 37 is associated. Thermo-sensitive elements 43, 44 and 45 are included in the heating chamber 40 and are arranged relatively to the heater 42 so that their temperature is at all times closely alike. Resistance 43 is connected to control the gain of repeater 11, and resistances 44 and 45 may be similarly connected to other repeaters, not shown.

The operation will now be described. It will be assumed that the thermo-sensitive elements 43, 44 and 45 have a negative temperature coefficient of resistance such as silver sulphide which is preferred because of its large coefficient, constancy and uniformity of performance as disclosed more fully in Fisher-Mallinckrodt application Serial No. 18,218, filed April 25, 1935. On this assumption, as the temperature of the cable increases increasing the transmission loss, the temperature of the heating chamber 40 must also increase to compensate for this loss. For, with an increase in temperature in heat chamber 40, the resistance of element 43, for example, decreases causing this element to shunt a greater portion of the current in the feed-back circuit of amplifier 11. This reduces the amount of feed-back and since the feed-back is a gain reducing feed-back, this results in raising the amplification in the repeater 11 as is necessary to compensate for an increase in transmission loss of the line 10.

It is necessary, therefore, for an increase in resistance, caused by an increase in temperature, of the pilot wire 13 to effect, through the medium of bridges 15 and 16 an increase in the temperature of the chamber 40. Let it be assumed that the temperature of the cable is increasing and that the bridge 15 becomes unbalanced as a result. Automatic galvanometer 25 moves shaft 26, rotating switch-arms 22 and 27 through an angle proportional to the unbalance of the bridge. Switch-arm 22 in moving over resistance 21 rebalances the bridge. Switch-arm 27 in moving over resistance 28 unbalances bridge 16. Bridge 16 becoming thus unbalanced impresses alternating current impulses on the grid circuit of the gas-filled tube 37. Source 36 also is impressing alternating current voltage on the plate circuit of tube 37. Since it is assumed that the direction of unbalance in the bridge circuit 5 is such as to call for heating current in resistance 42 to raise the temperature of the chamber, the phase of the voltage impulses impressed on the grid of tube 37 must be properly related to the phase of the plate voltage of this tube to enable the positive portions of the grid wave to cause current flow through tube 37 and the resistance 42.

As the temperature of heating chamber 40 is raised in this manner, the resistance of thermo-sensitive element 41 which may be silver sulphide or platinum or copper or any other suitable material, changes its resistance in a direction to rebalance the bridge 16. Assuming, for simplicity, that the switch-arm 27 remains stationary during this process, bridge 16 becomes rebalanced in response to an increase in temperature of the chamber 40 and the voltage pulses impressed on the grid of tube 37 through transformer 35 fall to zero or to too low a value to permit further discharge through tube 37. Resistance 43 now has its temperature raised a sufficient amount to increase the amplification of the repeater 11 to

compensate for the assumed increase in transmission loss of line 10 due to the assumed increase in temperature.

If the cable temperature remains at a fixed value for a considerable length of time, it is necessary to maintain the temperature of the heating chamber 40 at the appropriate fixed value. It is assumed that the entire regulating range of the chamber 40 is above the highest room temperature and that the heating chamber 40 is losing heat through the atmosphere continually at a suitable rate which can be controlled by the heat conductivity of the walls of chamber 40. As the temperature of the heating chamber 40 begins to fall, resistance 41 undergoes a resistance change and unbalances bridge 16 in a direction to permit alternating current impulses to be applied to the grid of the tube 37 and cause current to flow through that tube and through heater element 42 to increase the temperature of the heating chamber, causing the bridge 16 to be rebalanced by a change of resistance of element 41. By this means the heating chamber 40 is maintained at nearly constant temperature at any temperature level that may be necessary, the amount of heat supplied to maintain a high oven temperature being greater than that necessary to maintain a relatively low oven temperature. This greater amount of heat is supplied to maintain the high temperature by a more frequent unbalance of the bridge 16 than occurs at a low temperature.

If the temperature of the cable falls, bridges 15 and 16 become unbalanced in the general manner described above and alternating current voltage is applied to the grid of the tube 37 through coupling 35. For this direction of unbalance, however, the phase is reversed with reference to the type of unbalance first considered and the grid potential is always maintained sufficiently negative when the anode becomes positive to prevent any discharge through the tube 37. The heating chamber 40 is therefore allowed to drop in temperature until it is checked by the rebalancing of bridge 16 due to the cooling of the element 41 to the temperature corresponding to the new setting of arm 27 on resistance 28.

One advantage of using the two bridges 15 and 16 is a greater flexibility of control with a possibility of greater accuracy. For example, it is necessary, for the most accurate temperature compensation, that the rate of change of resistance of element 43 be properly related to the rate of change of resistance of the cable with temperature. Depending on the characteristic of resistance 43, the characteristic of the heat chamber control and of the various other elements of the control system, the temperature of the chamber may need to bear some non-uniform or irregular relation to the degree of unbalance of bridge 15. Bridge 16 may be made to have a different degree of unbalance than bridge 15 and the ratio of the two unbalances may vary. One way of accomplishing this is to taper resistance 28 or give it some irregular shape determined upon by trial, for example. The tapered resistance thus enables the temperature of chamber 40, and hence the resistance of element 43, to follow the change in cable temperature accurately in accordance with any specific and special law.

Referring now to Fig. 2, pilot conductor 13 is shown leading to a bridge 50 comprising arms 63, 64 and 65 and 66. Pilot conductor 13 forms

a part of arm 63, battery 67 furnishing current for the bridge. The line corresponding to line 10 and the repeater 11 are not shown in Fig. 2, but a similar group of lines each containing a 5 repeater similar to 11 may be assumed. The thermo-sensitive correcting elements for regulating the gain of the repeaters are shown included within a plurality of ovens or heat chambers of which two are shown by way of example 10 at 40 and 140. The thermo-sensitive elements are shown as at 43 and 143. Any desired or convenient number of thermo-sensitive elements may be included in each chamber and there may be as many heating chambers as desired.

15 In order to make the bridge 50 and gas-filled tube 37 common to a large number of repeaters and several heat chambers, a switching arrangement is provided comprising continuously running motor 53, operating through a reduction 20 gearing 55 if necessary, to rotate a shaft 54 on which are mounted three switch-arms 57, 59 and 61 cooperating respectively with contact arcs 56, 58 and 60.

It is believed that the nature of the apparatus 25 will best be understood from considering its operation which is as follows. At the particular instant of time represented by conditions shown in the drawing, switch arm 61 is in contact with the thermo-sensitive element 41 of the chamber 30 40 connecting that element through translating network 52, if a network is used, to the bridge arm 56 of bridge 50. Switch-arm 59 is connecting the grid circuit of gas-filled tube 37 in the galvanometer diagonal of the bridge 50, the grid circuit including a suitably high inductance 35 70. The switch-arm 57 is just about to connect the plate or discharge circuit of the gas-filled tube 37 to the heater 42 of heat chamber 40.

If, with conditions as represented in the drawing, the temperature of the pilot conductor 13 40 is such as to require the temperature of the heat chamber 40 to be raised, the bridge 50 is unbalanced and a small unbalance current flows from battery 67 through switch-arm 59 and high inductance 70 to ground. Switch-arms 61 and 59 45 are set slightly in advance of brush 57 so that they break their contacts an instant before arm 57 makes its contact. When the unbalance current assumed to be flowing in inductance 70 is thus broken a high electromotive force is developed across the coil, which is critically damped 50 so that but a single impulse of current builds up and is dissipated without appreciable current reversal taking place. Contact arm 57 closes the anode circuit of tube 37 while this relatively large 55 voltage exists across coil 70, and the tube 37 breaks down and transmits current into the heater 42. A certain quantity of heat is thus put into heat chamber 40 determined by the length of time that switch 57 remains in engagement 60 with the contact leading to heater element 42.

As stated, however, motor 53 is continuously rotating so that switch-arms 57, 59, and 61 remain on given contacts for only a brief instant 65 of time. When the switch-arm 57 leaves its contact, the plate circuit of gas tube 37 is broken and the discharge stops in the tube. Without considering for the moment the intermediate steps, let it be assumed that the shaft 54 makes a complete revolution again bringing contact 70 arms 57, 59 and 61 on the same contacts as are shown in the drawing. If the heat which was previously injected into the heat chamber 40 was sufficient to raise the temperature of thermo-sensitive element 41 to bring bridge 50 to a con-

dition of balance, then at the moment under consideration no positive voltage is applied to the grid of the gas tube 37 and the switch-arms 57, 59 and 61 pass over the contacts with which they 5 are shown in engagement without causing the tube 37 to discharge.

If the temperature of the conductor 13 falls, requiring the temperature of the heat chamber 40 to fall, the first effect is an unbalance of the bridge 50 in such direction that the unbalance 10 current through coil 70 is in the reverse direction to that considered before, and when this current is broken by movement of switch-arm 59 off its contact the resulting discharge of coil 70 15 applies negative voltage to the grid of the gas tube 37 preventing that tube from discharging. Heat chamber 40 being always at a temperature above room temperature is then allowed to cool down until a point is reached where with successive rotations of the switch arm, the bridge 20 50 becomes slightly unbalanced in the reverse direction and causes some heat to be put into the oven 40. It will be observed that identically the same kind of operation occurs in connection with heat chamber 140 as has been described for heat 25 chamber 40, such operation taking place as a result of the switch-arms 57, 59 and 61 making contact with leads extending to heater element 142 and thermo-sensitive element 141 of heat chamber 140. 30

The best speed of rotation of shaft 54 can be determined by trial to suit any given condition.

The network 52 may be used to assist in obtaining the proper relationship between pilot wire resistance and the temperature of the heat chamber, 35 and the charges in both.

It will be noted that in the circuits of both Fig. 1 and Fig. 2 the bridge balance which controls application of heating current to the heater is made a function not only of the pilot wire resistance but also of the temperature of the heat chamber. This automatically compensates for variations in temperature of the atmosphere surrounding the heat chamber, for only so much heat is applied as is required to rebalance the bridge, which means that the oven temperature 45 is at the correct value. If the room temperature is low, more current is required to reach a given high temperature within the heat chamber but, in any case enough current is applied to 50 accomplish this.

The circuit of Fig. 2 is well adapted for use in repeater stations where the groups of repeaters controlled by separate heat chambers 40, 140, etc. are so located that the heat chambers have 55 different rates of cooling. In such cases some heat chambers require supply of heat at quite a different rate from others. This is facilitated by the circuit of Fig. 2.

Referring to Fig. 3, pilot wire 13 leads to a 60 bridge composed of arms 71, 72, 73 and 74, the pilot wire forming all or part of the resistance of arm 71. Automatic galvanometer 25 turns a shaft which moves two arms 77 and 78 over resistances 75 and 76 respectively. Resistance 75 65 forms a part of arm 71 of the bridge. Resistance 76 controls the heating current, from source 82 to the plurality of heat chambers 83, 84, etc., the heater resistances being not shown in this figure. Resistances 85 and 86 are the heat-sensitive resistors connected to the various repeaters as in Fig. 1 to control their gains. 70

As the bridge becomes unbalanced due to a change in resistance of the pilot wire 13, galvanometer 25, as in Fig. 1, moves its shaft varying 75

arms 77 and 78. Arm 77 by varying the amount of resistance 75 that is effectively in arm 71 of the bridge restores the bridge balance. Corresponding movement of arm 78 increases or decreases, as the case may be, the amount of current that is being continuously supplied from source 82 to the different heat chambers. These heat chambers are assumed to have temperatures above room temperature throughout their entire range of adjustment, and therefore to be continuously losing heat to their surroundings. Resistance 76 and its rate of change are proportioned to supply to the heat chambers for each adjustment position an amount of heat energy sufficient to make up for the heat loss and to maintain the temperature of each heat-sensitive resistance 85, 86 etc. at the proper value for that adjustment.

Since the regulation is a function of the rate of cooling of the heating chambers, the accuracy or effectiveness of the regulation will depend upon the temperature of the surrounding atmosphere assuming that this is permitted to vary. In order to correct for such a variable influence on the operation of the regulator, resistance 80 exposed to the atmosphere in the vicinity of the heating chambers is inserted in the proper arm of the bridge in any suitable manner, for example in parallel with a portion of the resistance of bridge arm 72 or as shown, in series therewith. The resistance 80 may be a piece of silver sulphide exposed to the ambient temperature of the surroundings of heat chambers or it may be any other heat-sensitive material, for example, a coil of copper wire. Since the variations in resistance of element 80 must be properly related to the temperature effects in the heat chambers that are to be corrected, and to the regulating characteristics of the circuit, it may be necessary or desirable to employ a network 79 for suitably modifying the effect of changes in resistance element 80 on the regulating circuit. Network 79 may be a network of resistances or other elements for accommodating the rate of variations of resistance of element 80 to the rate of variation required by the regulating circuit.

Assuming the element 80 to have a positive temperature coefficient of resistance, if the room temperature rises, the resistance of element 80 increases. Also the heating chambers lose heat to the atmosphere less rapidly and therefore less heat needs to be supplied to the heat chambers to maintain them at any given temperature. From the standpoint of the amount of heat required, this represents a change in the same direction as that corresponding to a cooling of the cable including the pilot conductor 13, which represents a lowering of the resistance of the arm 71 of the bridge. This same effect can be simulated by an increase in resistance of bridge arm 72 by the increase in resistance assumed for element 80.

The invention is capable of variation and modification within the spirit and scope of the appended claims.

What is claimed is:

1. In combination with a line subject to variations in transmission characteristic, a thermo-sensitive resistance for producing compensating changes in the transmission characteristic of said line in response to temperature changes in said resistance, current-operated means determining the temperature of said resistance and a grid-controlled gas-filled tube, said current-operated means being connected in the anode

circuit of said tube in series relation with a source of alternating current, a coupling from said source to the grid of said tube, capable of impressing on the grid waves from said source in either of two phases, and means actuated in response to a change in the line transmission characteristic for controlling application to said grid of waves from said source and for determining the phase in which said waves are applied to said grid by said coupling.

2. In a transmission regulating means, a heat chamber including a temperature-affected transmission regulating element, means to control the temperature of said heat chamber, and means to compensate the effect on said heat chamber of variations in atmospheric temperature comprising a temperature-sensitive element exposed to atmospheric temperature changes, said last means modifying the operation of said first means in the control of the temperature of said heat chamber.

3. In a transmission regulating system, a plurality of repeaters of different location within a control area, heat chambers associated with different ones of said repeaters, means controlled by said heat chambers for controlling the gain of the respective repeaters, a common heating-control mechanism for determining the heating of said heat chambers, switching mechanism associating said common mechanism with said heat chambers in rotation and means directly controlled by said heat chambers for modifying the controlling action of said heating control mechanism.

4. In a cable transmission system, in combination with a cable containing a multiplicity of transmission lines, a repeater per line at a given repeater point, a pilot wire control system for controlling the gain of all of said repeaters to compensate for changes in cable attenuation, heat chambers including temperature-controlled means for determining the gain of said repeaters and switching means for operatively associating said control system with different ones of said heat chambers in rotation to regulate the repeater gains, said control system being in part controlled in response to the temperature of the individual heat chamber with which it is at the time associated.

5. In combination with a cable containing a multiplicity of lines, a repeater per line at a repeater point on said cable, a pilot wire regulating mechanism, thermal elements associated with said repeaters for regulating their respective gains, heaters associated with said thermal elements to control their temperatures, and switching means for operatively associating said pilot wire mechanism with said heaters in succession to control the supply of heat to each heater in accordance with gain change requirements of said repeaters, said pilot wire mechanism being in part controlled in response to the temperature of the individual heater with which it is at the time associated.

6. In a regulating system for transmission lines including repeaters, said system comprising a pilot conductor and a Wheatstone bridge controlled thereby, a heat chamber containing a thermo-sensitive gain controlling element, means controlled by an unbalance condition of said bridge to vary the amount of heating current supplied to said heat chamber, and means also connected to said bridge for governing the supply of heating current to said heat chamber as re-

quired under different conditions of room temperature.

7. In a regulating system for transmission lines, including repeaters, a pilot conductor, a
5 Wheatstone bridge controlled thereby, a heat chamber containing a thermo-sensitive element adapted to control the gain of a repeater, a source of heating current for said heat chamber, means controlled by an unbalance condition of said
10 bridge to control the supply of heating current to said heat chamber to vary the temperature of its interior to different temperatures all above room temperature, and means independent of

said pilot wire for controlling the balance of said bridge to control the supply of heating current to said heating chamber.

8. A combination according to claim 7 in which the last recited means is a thermo-sensitive resistance connected to said bridge and included
5 inside the heating chamber.

9. A combination according to claim 7 in which the last recited means is a thermo-sensitive resistance connected to said bridge and positioned
10 to take up a temperature similar to that of the surroundings of the heat chamber.

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