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SELECTIVE SYSTEM

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FIG. 1

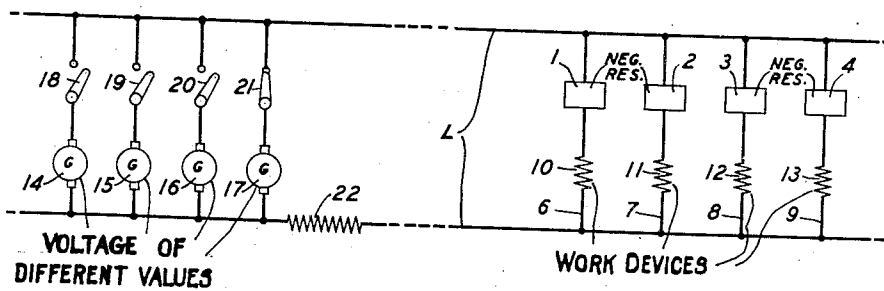
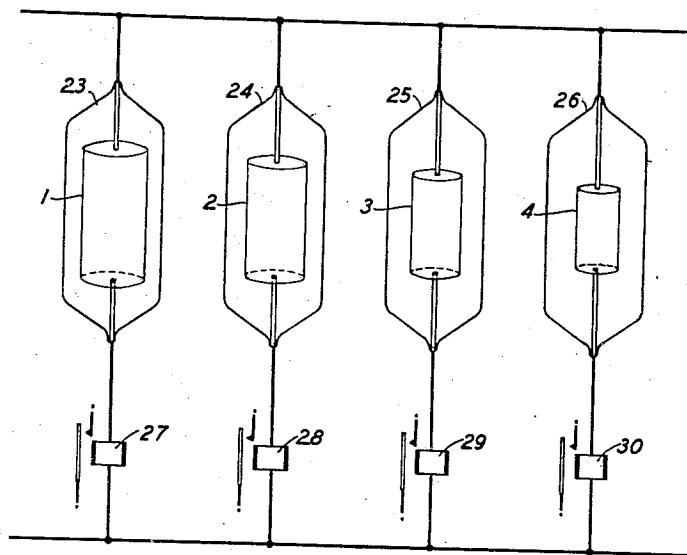


FIG. 2



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SELECTIVE SYSTEM

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8 Claims. (Cl. 177—353)

This invention relates to switching and signaling systems and particularly to those in which the operations are of a selective character.

The objects of the invention are to simplify selective switching circuits, to obtain greater selectivity, to increase the range of selections; to obtain greater precision and efficiency; and otherwise to improve systems of this kind.

According to a feature of the invention these objects are obtained by means of a system in which a common transmission line is provided with a plurality of branches or stations permanently associated therewith; in which the several branches are provided with individual resistors having large temperature coefficients of resistance and critical temperature points in their temperature-resistance characteristics; in which the thermal capacities of the successive resistors are graded to obtain different time intervals between the application of potentials to the line and the heating of the corresponding resistors to their critical temperature points; and in which the successive resistors are so constructed and arranged that their critical voltages are also graded, whereby any one of the several branches may be selected by applying to the line the corresponding critical voltage, which serves to raise the temperature of the resistor in that branch to its critical temperature point within the time interval characterizing that particular resistor. As soon as any one of the resistors has been raised to its critical temperature point, its resistance is reduced rapidly to shunt the other branches on the line, preventing any one of them from thereafter reaching the corresponding critical temperature point.

By equipping the several branches with work devices, such as relays, lamps, or other signals, any desired switching or signaling operation may be performed at any selected one of the stations to the exclusion of the remaining stations on the line.

Other features and advantages of the invention will be discussed more fully in detail in the following specification and will also be set forth in the appended claims.

In the drawing accompanying the specification:

Fig. 1 is a schematic illustration of a transmission line having a plurality of parallel branches with variable resistance elements and work devices therein and a plurality of sources for applying selective voltages to said line; and

Fig. 2 illustrates the manner in which the variable resistance elements may be constructed

to obtain the necessary grading in the critical voltages and also the grading of the time delay intervals.

There are a number of known materials having substantial negative coefficients of resistance. Among these are silver sulphide and boron, which have extremely large negative temperature coefficients, and these materials besides have critical points in their temperature-resistance characteristics. As heat is applied to resistance elements made of these materials, the resistance of the element decreases at a comparatively slow rate at first, until enough heat is absorbed by the element to raise its temperature to its critical point. If the temperature is increased beyond the critical point, the resistance of the element drops at a rapid rate. These elements may be heated by the presence of electric currents flowing in them, and the voltage applied to the terminals of the resistance element which is sufficient to raise the temperature of the element to its critical point is known as the critical voltage for that particular element. It is also a general characteristic of such materials that their resistance to the flow of current is usually high at normal temperatures. While the invention is not limited to the use of any particular resistance material, best results may be had from those substances, such as the ones mentioned above, which have high temperature coefficients of resistance.

The invention will best be understood from a detailed consideration of the drawing, wherein the line L is provided with a plurality of branches 6, 7, 8, 9, etc., including respectively the variable resistance elements 1, 2, 3, 4 and respectively the work devices 10, 11, 12, 13. At the other end of the line sources of voltage are provided. These sources, which are illustrated as generators, 14, 15, 16, 17, are connectable to the line L by means of switches 18, 19, 20, 21. A resistance 22, having a value substantially greater than the resistance of any one of the work devices 10, 11, 12, 13, is connected in series with the line.

With the variable resistance elements 1, 2, 3, 4 in the respective branches properly designed and proportioned and properly controlled, it is possible to select any desired one of the branches to the exclusion of all other branches by applying to the line L a selecting voltage of the proper value. When this is done the variable resistance element in the desired branch, responding to the flow of current from the applied source, raises its temperature to the critical point before the variable resistance elements in the other branches

have been able to reach their critical temperature points. The element in the selected branch, having thus reached its critical temperature point, rapidly lowers its resistance and allows a corresponding large value of current to flow through its branch to operate the work device therein. The large flow of current through the selected branch causes a reduction in the voltage applied across the other branches, and this prevents the variable resistance elements in said other branches from reaching their critical temperature points. To obtain the desired operation above described, it is necessary that the variable resistance elements in the successive branches have different critical voltages and also different delay intervals in reaching their critical temperature points when subjected to voltages equal to or in excess of their critical voltages.

If then V_m represents the critical voltage of a variable resistance element, we may express the above requirement as follows:

$$V_{m1} < V_{m2} < V_{m3} \dots < V_{mn} \quad (1)$$

The interval required between the application of voltage to the line L and the raising of any one of the elements to its critical temperature point will depend upon the thermal capacity of the element. If then C represents the thermal capacity of a resistance element,

$$C_1 > C_2 > C_3 \dots > C_n \quad (2)$$

With the foregoing relation of critical voltages and thermal capacities, those elements having the lower critical voltages will have the larger thermal capacities and consequently larger delay intervals in reaching their critical temperature points. For example, the element 1 has the lowest critical voltage and will therefore advance to its critical temperature in response to the application of the lowest selecting voltage to the line L. This means that any one of the selecting voltages when supplied to the line is sufficient to heat the element 1 to its critical temperature. However, although element 1 has the lowest critical voltage, it has the longest delay interval and requires a greater time than any of the other elements to reach its critical temperature point. Similarly, element 2 has a critical voltage higher than that of element 1 but lower than that of element 3. And element 2 has a delay interval less than that of element 1 and greater than that of element 3. And a similar relation is true of all succeeding branches. If, therefore, it is desired to select any particular branch, such as branch 8, a selective potential corresponding to this branch is applied to the line L by closing the switch 20, all other switches being open, to connect the generator 16 across the conductors of the line. This selective voltage is sufficient to apply to the unit 3 a voltage which is as great as its critical voltage, which is greater than the critical voltages of elements 1 and 2, and which is less than the critical voltage of element 4 and succeeding elements. Having its critical voltage applied thereto, the element 3 will absorb heat from the current flowing therein and will raise its temperature to the critical temperature point within the delay interval characterizing the element 3. Since the voltage applied is insufficient to raise the element 4 to its critical temperature, it is of no consequence that the delay interval of element 3 is greater than that of element 4 and that the full value of the voltage applied across the branch 8 is also maintained across branch 9 for a time in

excess of the delay interval of element 4. Consequently the branch 8 is selected to the exclusion of branch 9 and all others to the right thereof. As to branches 6 and 7, it is true that the voltage applied across these branches exceeds the critical voltages of elements 1 and 2. However, the voltage across branches 6 and 7 is maintained only for the duration of the delay interval of element 3, which is less than the time required for either element 1 or 2 to reach its critical temperature point. Therefore, the element 3 reaches its critical temperature point, lowers its resistance, and reduces the potential applied across branches 6 and 7 before the elements in either of these branches can reach their critical temperatures. In a similar manner any branch in the series may be selected and rendered effective to the exclusion of all other branches.

Consideration will now be given to the design and control of the resistance elements whereby it is possible to obtain the grading in critical voltages and the reverse grading in the delay intervals above described. It is known that the resistance characteristic of semi-conducting materials may be expressed in general by the equation,

$$R = R_0 e^{-\alpha T} \quad (3)$$

where

R = resistance at temperature T

T = temperature in degree centigrade above room temperature

R_0 = resistance of the unit at room temperature

$\epsilon = 2.718$

α = a constant

When $T = 0$, $R = R_0 e^0 = R_0$

The power absorbed by the unit may be expressed:

$$kT = \frac{V^2}{R} \quad (4)$$

where,

k is the radiation constant and V is the applied voltage.

From Equation (4) it follows that

$$T = \frac{V^2}{kR} \quad (5)$$

Eliminating T in Equations (3) and (5), we obtain

$$R = R_0 e^{-\frac{\alpha V^2}{kR}} \quad (6)$$

$$V = \sqrt{\frac{kR}{\alpha} \log \frac{R_0}{R}} = \left(\frac{kR}{\alpha} \log \frac{R_0}{R} \right)^{\frac{1}{2}} \quad (7)$$

Taking the derivative of V with respect to R , we obtain

$$\frac{dV}{dR} = \frac{1}{2} \frac{1}{\sqrt{\frac{kR}{\alpha} \log \frac{R_0}{R}}} \left[\frac{k}{\alpha} \log \frac{R_0}{R} - 1 \right] \quad (8)$$

It is known that the voltage-resistance characteristics of these materials have their slopes substantially equal to zero at the critical voltage values. Therefore, if we put the slope

$$\left(\frac{dV}{dR} \right)$$

of the curve equal to zero and factor out the term

$$\frac{1}{2} \frac{1}{\sqrt{\frac{kR}{\alpha} \log \frac{R_0}{R}}}$$

we obtain

$$\log \frac{R_0}{R} - 1 = 0 \text{ or } \log \frac{R_0}{R} = 1 \text{ or } \frac{R_0}{R} = e \quad (9)$$

When the applied voltage V is equal to the critical voltage V_m ,

$$R = R_m = \frac{R_0}{\epsilon} \quad (10)$$

where R_m is a resistance at the critical voltage. Combining (7) and (10) to eliminate R ,

$$V_m = \left(\frac{k R_0}{a \epsilon} \log \frac{R_0}{\left(\frac{R_0}{\epsilon} \right)} \right)^{\frac{1}{2}} \quad (11)$$

or, since $\log \epsilon = 1$,

$$V_m = \sqrt{\frac{k R_0}{a \epsilon}} \quad (12)$$

Also, starting with the general Equation (3), the following approximate relation may be derived:

$$t = \frac{C R_0}{a \epsilon (V^2 - V_m^2)} \quad (13)$$

t = time required for the element to reach its critical temperature

C = mass of the unit times its specific heat

k = radiation constant of the element

Rewriting expressions (12) and (13) by way of recapitulation we have

$$V_m = \sqrt{\frac{k R_0}{a \epsilon}} \quad (14)$$

$$t = \frac{C R_0}{a \epsilon (V^2 - V_m^2)} \quad (15)$$

And from these Equations (14) and (15) we may determine how to design and construct the variable resistance elements to be used in the successive branches 6, 7, 8, 9, etc., to satisfy the requirements. An inspection of these equations shows that the critical voltage V_m is independent of the delay interval t . So far as these variables are concerned, therefore, it is possible to design a series of resistance elements which will have progressively increasing values of critical voltage and at the same time will have progressively decreasing values of time delay, and this is what is required in the circuit disclosed in Fig. 1.

The desired grading in the critical voltages V_m of the successive units may be obtained by holding the resistance R_0 constant for successive units and by placing the successive units in different media. The atmosphere or medium surrounding the unit determines the rate of heat dissipation, on which the radiation constant k depends. For example, the unit 1, which requires the lowest radiation constant, may be enclosed in vacuo. The degree of vacuum may be varied, or air, or other gases, may be used for succeeding units. Heavier gases could then be used, and finally liquids, such as distilled water, may be used for the units requiring the largest values of k . If necessary the rate of heat dissipation may be controlled by pumping or otherwise moving the medium surrounding the elements. Having thus graded the critical voltages of the successive elements in the series, the remaining requirement is to grade the time delay intervals. From Equation (15) it will be seen that the time delay interval t is directly proportional to the thermal capacity C and is therefore directly proportional to the mass of the element. From this it follows that the time delay intervals may be graded by graduating the masses or volumes of the successive resistance elements. But in doing this the values of R_0 must be held constant, since this term occurs in Equation (14) and is a function of the critical voltage. It will now be demonstrated that the

resistance elements may be so designed that their volumes are graded to give the desired grading in the values of t while at the same time maintaining the values R_0 constant.

Assume that the successive resistance elements 1, 2, 3, 4, etc., are made in the form of cylinders as illustrated in Fig. 2 of the drawing. And considering a cylinder of the resistance material, we may express its thermal capacity C by the equation

$$C = b \text{ vol} \quad (16)$$

where

b = a constant

vol = volume of the cylinder.

Also,

$$\text{vol} = l S \quad (17)$$

where

l = length of cylinder

S = area of a right section of cylinder.

Combining Equations (16) and (17), we have

$$C = b l S \quad (18)$$

If we let ρ equal the specific resistance of the material at zero current and room temperature, we have

$$R_0 = \frac{l \rho}{S} \quad (19)$$

Since R_0 is to remain constant, the ratio

$$\frac{l}{S} = d, \text{ a constant, and} \quad (20)$$

$$S = \frac{l}{d}$$

Combining Equations (18) and (20), we have

$$C = \frac{b l^2}{d} \quad (21)$$

Considering now any two resistance units in the series, such as units 1 and 2, we may express the thermal capacities of these units as follows:

$$C_1 = \frac{b}{d} l_1^2 \text{ and } C_2 = \frac{b}{d} l_2^2 \quad (22)$$

Taking the ratio of these expressions we have

$$\frac{C_1}{C_2} = \left(\frac{l_1}{l_2} \right)^2 \text{ or } \frac{l_1}{l_2} = \sqrt{\frac{C_1}{C_2}} \quad (23)$$

Returning to Equation (20) and expressing it in terms of length,

$$l = d S \quad (24)$$

Combining Equations (18) and (24) to eliminate l ,

$$C = b d S^2 \quad (25)$$

Considering again the two cylinders 1 and 2, their thermal capacities may be expressed in terms of S

$$C_1 = b d S_1^2 \text{ and } C_2 = b d S_2^2 \quad (26)$$

Taking the ratio of these expressions, we have

$$\frac{C_1}{C_2} = \left(\frac{S_1}{S_2} \right)^2 \text{ or } \frac{S_1}{S_2} = \sqrt{\frac{C_1}{C_2}} \quad (27)$$

With Equations (23) and (27) we may, therefore, determine the sizes of any two of the units to satisfy any required ratio of thermal capacities. In Fig. 2 a number of units are illustrated in the form of cylinders 1, 2, 3, and 4 of progressively decreasing volumes. The dimensions of these cylinders may be calculated in accordance with the derived equations to give the proper grading of delay intervals and to maintain the values of R_0 constant. The successive resistance units may be mounted in any suitable containers, such as the containers 23, 24, 25, and 26. These containers may be evacuated to differ-

ent degrees or filled with gases or liquids to give the required values for the radiation constants. Also, as described herein, means may be provided for circulating the heat dissipating medium by pumping air, gases, or liquids through the containers in which the resistors are mounted.

It will be obvious that a system of this kind will have many practical applications. The parallel branches may be provided with relays 27, 28, 29, 30 for closing work circuits to perform any one of a wide number of functions. Also signals, such as bells or lamps, may be included in the parallel branches for selective operation. Another possible use would be to select subscribers' stations on a party line for secret communication to the exclusion of other parties on the same line.

What is claimed is:

1. In combination, a transmission line, a series of branches connected permanently across the conductors of said line, elements in said branches having negative temperature coefficients of resistance and critical points in their voltage-resistance characteristics, the successive elements of the series having progressively increasing critical voltages and progressively decreasing thermal capacities, and means for applying different potentials to said line to cause the resistance of any desired one of said elements to reach its critical value in advance of the other elements.

2. In combination, a plurality of resistance elements having negative temperature coefficients of resistance and critical temperature points, said elements being of different sizes and of progressively decreasing thermal capacities to give them different delay time intervals for reaching their critical temperature points, a transmission line, means for connecting said elements respectively in parallel branches across said line, sources of voltage for heating said elements, means for controlling the radiation characteristics of each element to give said elements progressively increasing critical heating voltages, selective means for applying to the line a voltage corresponding to the critical heating voltage of any desired element to lower the resistance of such element within its delay interval and shunt all other elements, and work devices in the respective branches, the device in the selected branch being operated to the exclusion of all other devices.

3. The combination with a transmission line of two branches permanently connected across said line in parallel to each other, resistance elements, one in each branch, having large temperature coefficients of resistance and critical points in their voltage-resistance characteristics, one element having a lower critical voltage and a higher thermal capacity than the other element, means for producing voltages of different values, and means for connecting said voltages selectively to the line to cause a desired one of said elements to reach its critical resistance value in advance of the other element and to shunt said other element by reason of the parallel relation of said branches.

4. The combination with a transmission line of a plurality of branches connected across said line in parallel relation, resistance elements, one in each branch, having negative coefficients of resistance and critical points in their voltage-resistance characteristics, the successive elements

having progressively increasing critical voltages and progressively decreasing thermal capacities, means for producing voltages of different values, and means for selectively applying said voltages to the transmission line to cause a desired one of said elements to reach its critical point and to assume a low-resistance value in advance of the other elements, the selected element on assuming its low-resistance value serving as a shunt for the other elements.

5. The combination with a transmission line of a plurality of branches connected across said line in parallel relation, resistance elements, one in each branch, having negative temperature coefficients of resistance and critical points in their voltage-resistance characteristics, the successive elements having progressively increasing critical voltages and being of different sizes to give them progressively decreasing thermal capacities, a means for producing voltages of different values, and means for selectively applying said voltages to the transmission line to cause a desired one of said elements to reach its critical point and to assume a low-resistance value in advance of the other elements, the selected element on assuming its low-resistance value serving as a shunt for the other elements.

6. The combination with a transmission line of a plurality of branches connected across said line in parallel relation, resistance elements, one in each branch, having negative temperature coefficients of resistance and critical points in their voltage-resistance characteristics, housing devices for said elements containing different media to give the successive elements progressively increasing critical voltages, said elements being of different sizes to give them progressively decreasing thermal capacities, means for producing voltages of different values, and means for selectively applying said voltages to the transmission line to cause a desired one of said elements to reach its critical point and to assume a low-resistance value in advance of the other elements, the selected element on assuming its low-resistance value serving as a shunt for the other elements.

7. In combination, a transmission line, a plurality of branches connected in parallel across the conductors of said line, variable-resistance elements in said branches, each of which has a critical point in its voltage-resistance characteristic, said elements having progressively increasing critical voltages and being of different sizes to give them progressively decreasing thermal capacities, and means for applying variable potentials to said line to cause the resistance of any desired one of said elements to reach its critical value in advance of the other elements.

8. In combination, a transmission line, a plurality of branches connected in parallel across the conductors of said line, variable-resistance elements in said branches, each of which has a critical point in its voltage-resistance characteristic, the critical voltages and the thermal capacities of the successive elements being graded in opposite senses, and means for applying different potentials to said line to cause the resistance of any desired one of said elements to reach its critical value in advance of the other elements.

ALEXIS A. LUNDSTROM.