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H. S. BLACK

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CONTROL OF ELECTROMAGNETS

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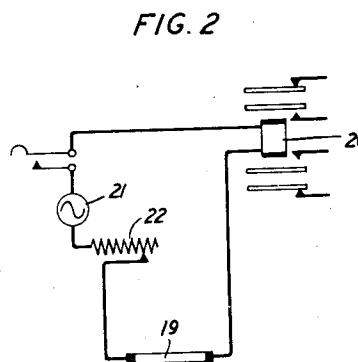
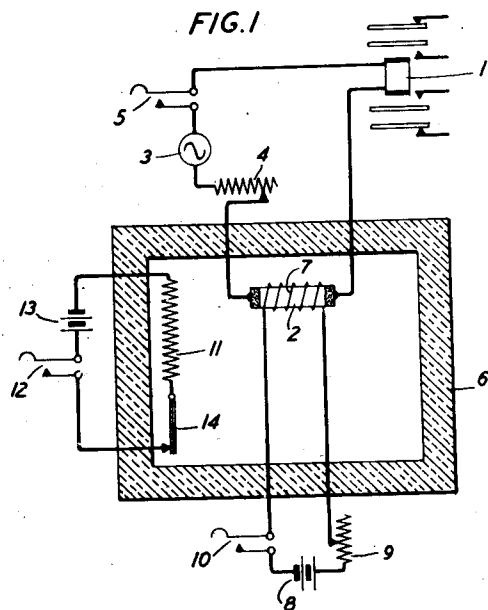
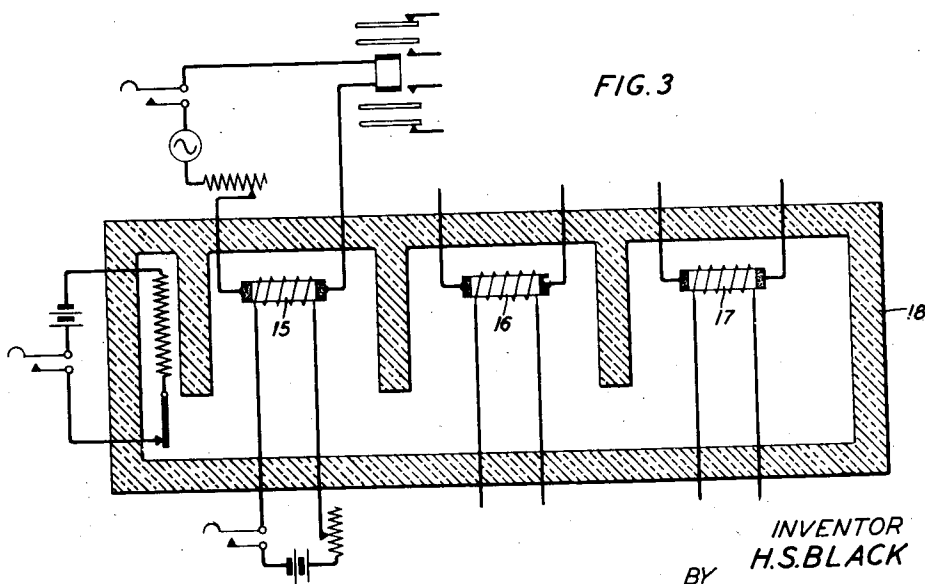
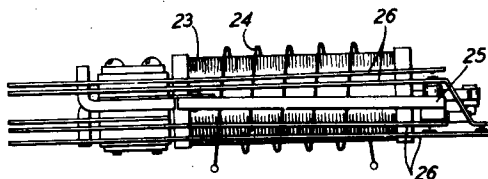


FIG. 4



INVENTOR
H.S. BLACK
BY *M. T. McJannet*
ATTORNEY

UNITED STATES PATENT OFFICE

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CONTROL OF ELECTROMAGNETS

Harold S. Black, Elmhurst, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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This invention relates to systems for the control of currents in electrical circuits and particularly for controlling the operation of electromagnetic devices, such as circuit-making relays, which are commonly used in telephone and other electrical systems.

The objects of the invention are to control the rate of change of current in an electrical circuit; to introduce delay intervals which may be made to vary with an extremely high degree of precision over a wide range; to obtain the required delay intervals in the operation of a relay without impairing its ability to release quickly; to obtain the required delay interval in the release of a relay without causing it to operate slowly; to secure these ends without the necessity of making any changes in the mechanical or magnetic construction of the relays themselves; and otherwise to effect improvements in these devices and in their performance.

Numerous inventions have been made heretofore for controlling the operating and releasing time of relays. One common method of obtaining a delay interval in the operation of a relay is to add a copper slug to the core of the relay. Another method is to time the action of the relay by condensers suitably connected in circuit therewith. Still another method is to utilize a thermostat for controlling the relay. Another kind of slow acting relay is one in which an oil controlled plunger mechanism is used. In most cases relays of this character derive their slow acting characteristic by reason of their inherent mechanical or magnetic construction, necessitating added complication and expense in their design and manufacture. Moreover, it has usually been the case that whatever is done in the design of the relay to increase either its operating time or its releasing time results respectively either in a corresponding retardation in the release time or a corresponding retardation in the operating time of the relay. This, of course, is objectionable in those cases, frequently met, where a relay is required to be relatively slow in one direction and fast in the other direction.

According to the present invention these disadvantages are overcome by introducing into the operating circuit of an ordinary relay, the construction of which is such that it attracts its armature quickly when full operating current is applied to its winding and releases quickly when its circuit is opened, a resistance unit of some substance having an extremely high negative temperature coefficient of resistance together with a proper critical voltage characteristic, and

by controlling the temperature of the unit to control the time required for the current in the relay circuit to reach the value at which the relay acts. Among those substances known to have a high temperature coefficient of electrical resistance I have found that silver sulphide is peculiarly well suited to this purpose. Its critical voltage characteristic and its extremely high negative temperature coefficient of resistance make it especially useful for the accurate measurement, over a wide range, of intervals of delay in the establishment of the full operating current value in the relay circuit. Its wide range of resistance together with the facility with which its temperature can be controlled make it possible to measure intervals of time which vary from a small fraction of a second to several minutes. Also its characteristics enable its use for operating a relay rapidly and then for introducing a delay interval in the release of the relay. It is relatively inexpensive, occupies very little space, is simple and rugged, and requires little or no maintenance attention. Boron is another substance having a high negative temperature coefficient of resistance and otherwise suitable for the purpose stated.

This invention is a circuit arrangement for controlling the operating and releasing time characteristics of a relay which comprises a resistor having a negative temperature coefficient of resistance connected in series with the relay and a source of potential of a given value, and means for applying heat from an external source to said resistor to raise its temperature sufficiently above the normal temperature to reduce the resistance of said resistor and permit sufficient current to flow in said circuit to operate the relay. Upon removing the external source of heat, the temperature of said resistor falls to the point where the resistance of said resistor reduces the current flowing in the circuit sufficiently to permit the release of the relay. By choosing the value of the applied potential and the size and resistance of the resistor and by properly selecting the temperature to which the resistor is raised by the external heating source, the operating time of the relay may be made as short as desired and the delay in the releasing time of the relay may be varied to suit requirements.

A feature of the invention is an arrangement wherein the temperature of the resistance unit is controlled both directly by the operating current in the work circuit and indirectly by a source of heating current in an auxiliary circuit. Another feature of the invention is a circuit

arrangement for controlling the rate of change of current in a circuit in which the dimensions of a resistance element having a negative temperature coefficient of resistance and a critical point in its temperature-resistance characteristic are so proportioned as to enhance its ability to dissipate heat, and in which the resistance of the circuit is so taken that the voltage across the resistance element is brought to the value necessary for raising the temperature of the resistance element to its critical point within the desired interval of time. The required delay interval in the operation of the relay may be obtained by the use of a resistance element which dissipates heat rapidly and thereby restores quickly to its normal temperature, permitting its use for successive operations of the relay.

Another feature is an arrangement for maintaining the resistance unit at some constant normal temperature beyond the influence of fluctuations in the surrounding room temperature, the controlling heating current serving to raise the temperature of the unit to the required point above this normal level to effect the desired time control over the relay circuit.

These and other features of the invention will be described more fully in the following detailed specification and will also be set forth in the appended claims.

The drawing which also constitutes a part of the specification comprises several figures, of which:

Fig. 1 illustrates a relay and its operating circuit including a source of potential, a resistor, and a variable resistance for controlling the voltage across the resistor. This figure also illustrates a heat insulated chamber for housing the resistor together with a heating circuit for applying heat to said resistor;

Fig. 2 shows a relay circuit somewhat similar to that of Fig. 1, except that the heat insulated chamber is omitted;

Fig. 3 illustrates a heat insulated chamber containing a plurality of the resistors; and

Fig. 4 illustrates a suitable form of relay for use in connection with this invention.

While I do not wish to limit my invention to the use of a resistor of any particular substance, I have found, as hereinbefore stated, that the properties of silver sulphide make it especially suitable for the purpose of controlling the action of electromagnets and relays. It has an extremely high negative temperature coefficient of resistance. The temperature-resistance relation of silver sulphide may be stated approximately thus: $R = R_0 e^{-0.05t}$ where R_0 is the resistance before the assumed temperature change of t degrees centigrade occurs and R is the resistance after this change of temperature has occurred. This relation holds for all temperatures between about 0°C. and 179°C. , at which latter temperature the resistance abruptly falls to about $\frac{1}{40}$ of its former value for an increase of less than 1°C. Above this transition temperature the material apparently behaves the same as a metal with a uniform small positive temperature coefficient. In addition to having this high temperature coefficient characteristic silver sulphide also has a critical voltage characteristic. By applying a voltage exceeding a certain minimum value to a particular specimen of the material, current will flow with an intensity which is small at first because of the extremely high resistance of the material at its lower temperature. This current creates heat, which raises the temperature and lowers

the resistance, in turn allowing more current to flow to raise the temperature still further and correspondingly decrease the resistance. As this process continues, the amount of heat thus received by the unit gradually approaches the amount of heat that the unit is capable of dissipating. When the amount of heat received equals the amount of heat dissipated the process has reached the critical point. From this point the temperature increases and the resistance decreases at a rapid rate. The critical voltage of the particular specimen is that voltage which is just sufficient to cause the temperature to reach the critical point above mentioned. Any voltage below the critical voltage will not be sufficient to cause enough current to flow to create heat faster than the unit is able to dissipate the heat received. Of the total time required for the resistance unit to reach its lower resistance value as a result of an applied voltage the larger proportion is consumed between the instant the voltage is applied and the instant that the critical point in the temperature-resistance characteristic is reached. Beyond this point the resistance diminishes at a much more rapid rate.

Because of the characteristics of this material above mentioned, it is possible to control, with considerable precision, the operating time of a relay and to vary the delay in the operation of the relay from a small value to a relatively large value. By selecting the proper dimensions for the resistor and the proper voltage for application to the circuit including the resistor and the relay to be controlled and also by introducing external heat for the purpose of controlling the temperature of the resistor, it is possible to obtain any desired interval of delay in the operation of the relay.

It is also possible because of these characteristics of silver sulphide to utilize it for the purpose of controlling the releasing operation of a relay. By applying heat to the resistor from an external source, sufficient current may be caused to flow in the circuit to operate the relay with any desired degree of rapidity. If the heating source is then removed and the resistor is permitted to cool gradually, it will require a given interval of time before the resistance is increased to the point where insufficient current flows in the circuit to maintain the relay operated. Therefore the relay releases when the current diminishes to this point. One convenient method of applying heat to the resistor to control its temperature is to provide a heating winding around the resistor and include this winding in series with a source of electrical current. Alternatively, any known method of applying heat may be used.

Referring now to the drawing, and particularly to Fig. 1, relay 1 may be caused to operate at the end of any desired predetermined interval following the closure of its circuit by including in said circuit a resistor 2 of some suitable substance, such as silver sulphide, having a negative temperature coefficient of resistance and properly chosen as to size and dimensions with respect to the other elements in the circuit. The relay circuit also includes a source 3 of alternating current of the proper voltage, regulating rheostat 4, and a circuit-closing key or contact 5. Although not necessary for the control of the relay, the resistor 2 is here illustrated as housed within a suitable heat-insulated chamber 6. The resistor 2 is provided with a heating winding 7 which is supplied with current over a circuit including a source 8, a regulating resistance 9, and a circuit-

controlling key or contact 10. The heating winding 7 is shown in the drawing as encircling the resistor 2, although it may, if desirable, be arranged in any other manner in proximity to the resistor. When the winding 7 is coiled about the element 2 as shown, some suitable electrical insulation should be interposed between the winding and element. In case it is desired to maintain the interior of the chamber 6 at some fixed temperature above the ambient temperature, this may be done by means of a heating unit 11 located within the chamber and supplied with current from a source 13. Also in circuit with the heating unit 11 is a thermostat 14, which is set to hold the temperature within the chamber 6 at the desired value. The heating unit 11 is rendered effective by means of a key or contact 12.

Having chosen the resistor 2 as to size and dimensions for controlling the relay 1, and taking into account the resistance of the relay 1 and its circuit, the interval of delay between the closure of the circuit and the operation of the relay will depend upon the voltage across the terminals of the resistor 2 and the amount of heat applied to said resistor by the heating winding 7. The voltage across the resistor 2 may be adjusted to the desired value by means of the rheostat 4, and the amount of heat applied to the resistor 2 may be regulated by the rheostat 9. The instant the contact 5 is closed, the potential of the alternating current source 3 is applied to the circuit. As a result of this a voltage is impressed across the terminals of the resistor 2, and current will flow in the circuit. The initial value of this current will depend upon the voltage across the resistor 2 and upon the temperature to which the resistor has been raised by the heating winding 7. The initial flow of current is too small to cause the operation of the relay 1. As this initial current flows through the resistor 2, it creates heat in the resistor, raising its temperature and correspondingly reducing its resistance, thereby permitting a still greater current to flow in the circuit. This process continues, the resistance of the element 2 decreasing and the current increasing until the current in the circuit becomes sufficient to operate the relay 1. If no heat or very little heat is applied to the resistor 2 from the external source 8, the heat necessary to raise the temperature of the resistor 2 will then be derived largely from the current flowing in the circuit. In this case the applied voltage, in order to obtain the maximum resistance from the resistor, will need to be equal to or somewhat in excess of the critical voltage—that is, the voltage necessary to create heat in the resistor 2 at a more rapid rate than the resistor is capable of dissipating such heat. However, by applying different amounts of heat to the resistor 2 from the external source, the applied voltage may be chosen at values below the critical voltage. Since the relay 1 may be one the construction of which is such that it attracts its armatures quickly when full current is applied and releases its armatures quickly when its circuit is opened, the delay interval introduced in its operation does not affect its fast release properties. As soon as the circuit is opened at contact 5 or at any other point, the relay quickly restores its contacts.

To obtain the highest degree of precision in the intervals measured between the closure of the circuit and the operation of the relay, the resistor 2 may be maintained at a constant normal predetermined temperature by closing the contact 12 and setting the thermostatic control in opera-

tion. The thermostat 14 may be of any known type and can be set to maintain the temperature within the chamber 6 at the desired normal level somewhat above the influence of the ambient temperature.

When it is desired to introduce a delay interval in the release of relay 1, the values of the different elements involved are so chosen that the relay 1 does not receive sufficient current to operate merely by closing the contact 5. With the contact 5 closed, however, if a considerable amount of heat is applied quickly to the resistor 2 by the winding 7, the current builds up rapidly in the circuit to the point where it operates the relay 1. This interval may be made very short so that the relay is in effect a fast operating relay. When the relay is to be released, the heating circuit is opened at contact 10 or elsewhere, and the resistor 2 is permitted to cool. As the cooling process takes place, the resistance of the unit 2 gradually increases, thus diminishing the current in the circuit until at the end of a definite interval of time the relay releases for the want of sufficient current to hold its armature. This interval may be varied at will by controlling the different variable quantities in the system.

Occasionally it is necessary to have a slow-operate relay which is capable of being repeatedly operated with relatively small intervening intervals of time. In such a case it might be that the resistor 2 would have insufficient time to cool to its normal or starting temperature before it was time again to operate the relay. To meet this requirement, the resistor element may be designed with a view to enhancing its ability to dissipate heat. In Fig. 2, for example, the resistor 19 is so constructed that it is capable of dissipating its heat rapidly as soon as the current ceases flowing. Since the resistor 19 is somewhat smaller in dimensions, its initial resistance is correspondingly less, and it is necessary, therefore, to reduce the voltage applied across the resistor from the source 21. This may be done by means of the rheostat 22. With the values properly adjusted, the required delay interval may be introduced in the operation of the relay 20, and, as soon as the circuit is opened to release the relay, the resistor 19 immediately cools and restores to its initial temperature, thereby putting the system in condition for reoperation to measure again the required delay interval before the relay 20 operates the second time.

In Fig. 3 a plurality of resistors 15, 16, 17 are housed within the same heat insulated chamber 18. These resistors may be controlled by separate heating windings and may serve to control separate relay circuits. If desirable baffles may be provided as shown to prevent an undue amount of heat transmission from one unit to another.

Fig. 4 illustrates one form of relay that may be used in the circuits above described. This figure shows a relay having a core 23, a winding 24, an armature 25 and spring contacts 26. Obviously the relay may be of any suitable design and construction, and the invention is no way limited to any particular type of relay.

The resistance units used in this invention may, of course, be constructed in any suitable manner; and, as hereinbefore explained, the invention is not limited to the use of any particular substance for the resistance element. Silver sulphide has been specifically mentioned as a good resistance material, and the resistance units of this material may be made by any suitable method. One

such method is disclosed in the patent of J. R. Fisher, 2,091,259 dated August 31, 1937.

Other modifications of the devices shown are also within the scope of the invention. For example, alternating current generators 3, 21, etc., are shown, but any suitable source of potential may be employed for supplying current to the operating circuits.

What is claimed is:

1. The combination with a relay of a circuit including the winding of said relay, a source of potential for application to said circuit, a resistance element having a negative temperature coefficient of resistance included in said circuit to effect a delay in the rise of current in the circuit to a value sufficient to operate said relay, a heat insulated chamber for housing said element, means for maintaining said chamber at a particular temperature, and means for applying heat to said element to control its temperature to in turn determine accurately the amount of said delay.

2. The combination with a relay of a circuit including the winding of said relay, a source of potential for application to said circuit, a resistance element having a negative temperature coefficient of resistance included in said circuit to effect a delay in the rise of current in the circuit to a value sufficient to operate said relay, a heat insulated chamber for housing said element, means for maintaining said chamber at a particular temperature, and heating means for applying heat to said element to raise its temperature a definite amount above said particular temperature to determine the amount of said delay.

3. The combination with an electromagnet, having a winding and an armature, of a circuit including said winding, a source of potential and means for connecting the same to said circuit, a resistor of silver sulphide included in said circuit for the purpose of introducing a delay interval between the application of said potential source and the energization of said winding sufficient to operate said armature, a heat insulated chamber for housing said resistor, thermostatically controlled means for maintaining the temperature of said chamber at a particular value above the ambient temperature, and means for applying heat to said resistor to raise its temperature a desired amount above said particular temperature to control accurately the length of said delay interval.

4. The combination with an electromagnet having a winding and an armature, of a circuit including said winding, a source of potential and means for applying the same to said circuit, a resistance element having a high negative temperature coefficient of resistance included in said circuit to introduce an interval of time between the application of said potential source and the energization of said winding sufficient to operate said armature, a heat insulated chamber enclosing said resistance element, and means for applying heat to said resistance element to control accurately the length of said interval.

5. The combination with an electromagnet having a winding and an armature, of a circuit including said winding, a source of potential and means for applying the same to said circuit, a resistance element having a high negative temperature coefficient of resistance and a critical point in its temperature-resistance characteristic included in said circuit to cause a time delay between the application of said potential source

and the rise of current in said circuit to a value sufficient to operate said armature, a heat insulated chamber enclosing said resistance element, and means for heating said resistance element to control the length of said interval.

6. The combination with a relay constructed to attract and release its armature quickly when said winding is energized and deenergized, respectively, of a circuit for the winding of said relay, a source of potential and means for connecting the same to said circuit, a resistor having a negative temperature coefficient of resistance included in said circuit for the purpose of introducing an interval of time between the application of said potential source and the energization of said winding sufficient to operate the armature of the relay, a heat insulated chamber enclosing said resistor, and means including said potential source for applying heat both directly and indirectly to said element to control the length of said interval.

7. The combination with a relay, having a winding and an armature, of a circuit including said winding, a source of potential for application to said circuit, a resistance element having a negative temperature coefficient of resistance included in said circuit to cause a desired delay in the increase of the current in said circuit to a value sufficient to operate the armature of said relay, an auxiliary circuit having a heat winding located in proximity to said resistance element for applying heat thereto, and a heat insulated chamber enclosing said resistance element and heating winding.

8. The combination with a relay, having a winding and an armature, of a circuit including said winding, a source of potential and means for connecting the same to said circuit, a resistor having a high negative temperature coefficient of resistance included in said circuit to delay the rise of current in said circuit to a value sufficient for the operation of said armature, an auxiliary circuit having a heating winding located in proximity to said resistor, a heat insulated chamber enclosing said resistor and said heating winding, and resistance means in said auxiliary circuit for controlling the flow of current therein to control the amount of heat applied to said resistor.

9. The combination with an electromagnet, having a winding and an armature, of a circuit including said winding, means for applying a potential to said circuit, a resistance element of silver sulphide included in said circuit for the purpose of introducing an interval of time between the application of said potential and the energization of said winding sufficient to operate said armature, a heat insulated chamber enclosing said resistance element, and means for applying heat to said resistance element.

10. The combination of a relay and a source of potential connected in a circuit, a resistance element having a high negative temperature coefficient of resistance and a critical point in its temperature-resistance characteristic included in said circuit, means for applying heat to said element to raise its temperature to the critical temperature to cause the operation of said relay, and means for applying heat to said element at a rate insufficient to maintain said element above the critical temperature, the time required for the temperature of said element to drop sufficiently to cause the release of said relay being a desired and predetermined interval of time.

11. The combination of a relay, a source of

potential and a resistor connected in a series circuit, said resistor having a negative temperature coefficient of resistance, the current in said circuit being insufficient to heat said resistor to a temperature high enough to cause operation of said relay, other means for applying heat to said resistor to raise the temperature of said resistor sufficiently to cause operation of said relay, the current in said circuit being effective after said relay is operated and heat is no longer being applied by said other means for delaying the cooling of said resistor to a temperature low enough to cause the release of said relay, the delay thus introduced being a desired and predetermined interval of time.

12. In combination, a relay, a source of potential, a resistor having a negative temperature coefficient of resistance and a critical point in its temperature-resistance characteristic, a circuit including said relay, said source and said resistor, means for closing and opening said circuit, and means for adjusting the current in said circuit to the value required for raising the temperature of the resistor to its critical point in

a desired interval of time, said resistor being proportioned to enhance its ability to dissipate heat so that, upon the opening of said circuit, said resistor will be quickly conditioned for again delaying the operation of said relay for the desired interval of time.

13. In combination, a source of potential, a relay and a resistor connected in series with said source, said resistor having a high temperature coefficient of resistance, a heat insulating enclosure for said resistor, means for regulating the temperature within said enclosure, means for applying heat to said resistor other than by the current in said circuit and for a long enough interval to cause the operation of said relay, and means for adjusting the current in said circuit to a value insufficient to maintain the temperature of said resistor to hold said relay operated, said current being effective to delay the cooling of the resistor and the release of the relay, the delay thus introduced being a desired and predetermined interval of time.

HAROLD S. BLACK.