

Aug. 7, 1928.

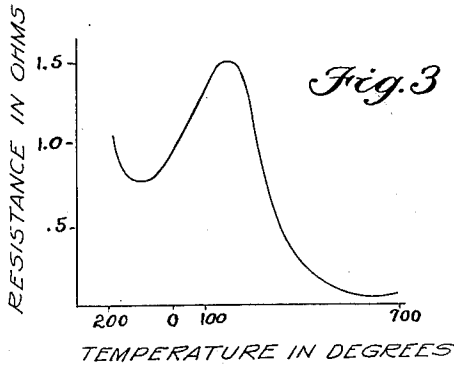
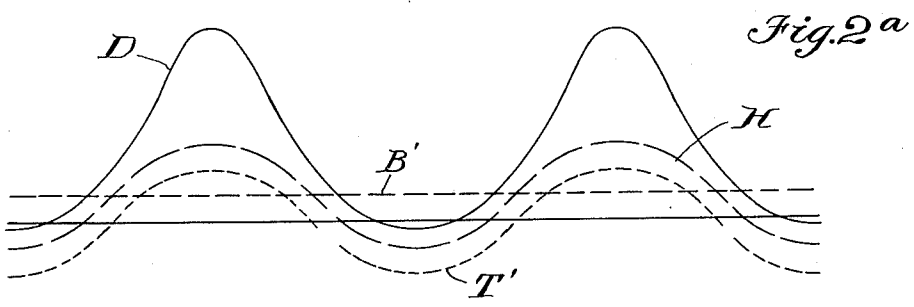
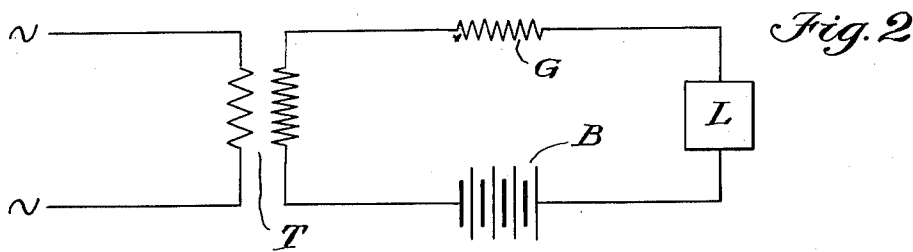
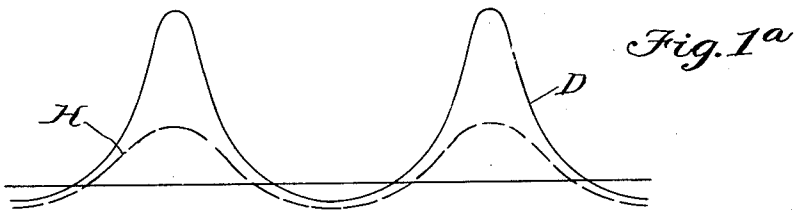
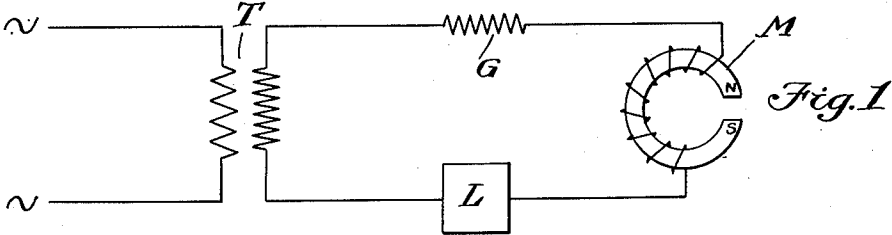
1,679,448

C. G. SMITH

ELECTRICAL CURRENT MODIFICATION

Filed May 22, 1923

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 4

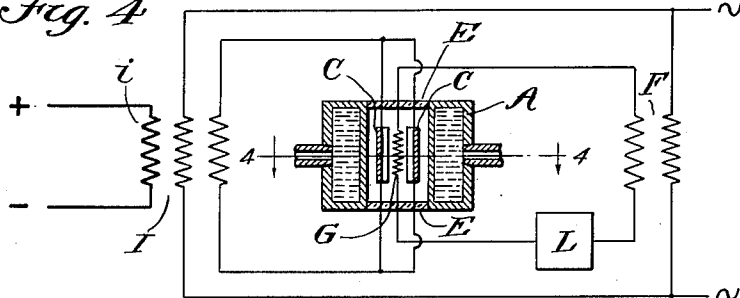


Fig. 4^a

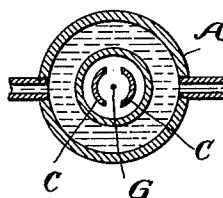


Fig. 4^b

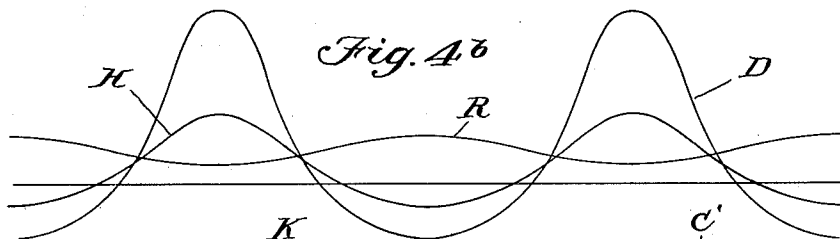


Fig. 5

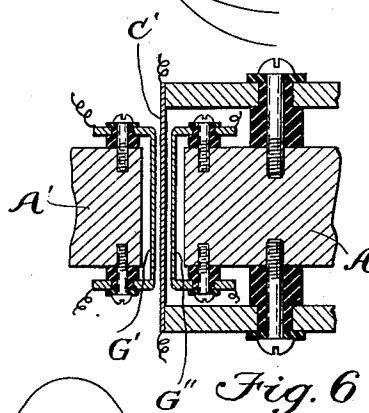
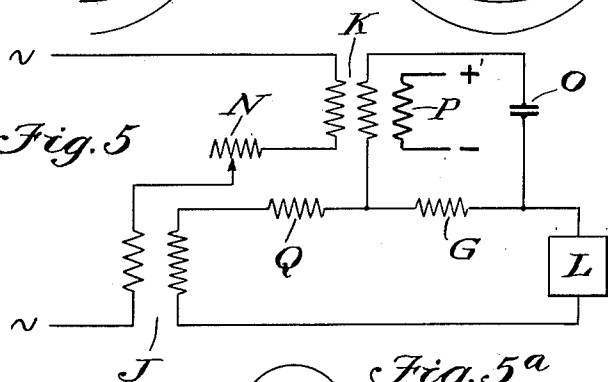


Fig. 5^a

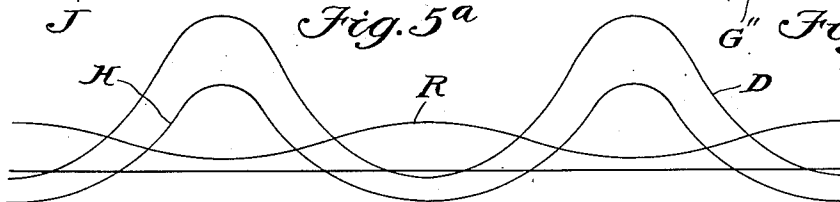
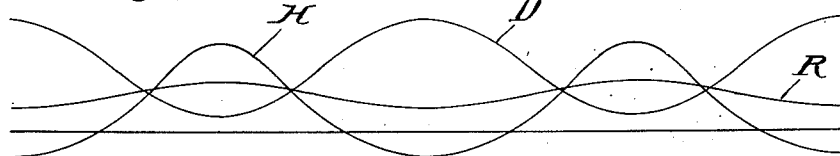


Fig. 5^b



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UNITED STATES PATENT OFFICE.

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ELECTRICAL-CURRENT MODIFICATION.

Application filed May 22, 1923. Serial No. 640,689.

Objects of this invention are to provide a simple and effective method of rectifying alternating currents or otherwise altering the character of electrical currents and to provide for the purpose apparatus which is inexpensive to construct and reliable in use.

The invention involves the use of a resistance element (or other impedance element) which has a steep temperature coefficient of resistance curve, that is, whose resistance changes rapidly in response to temperature changes. The temperature coefficient of resistance may be either positive or negative and preferably has both a positive and a negative range so that the coefficient may be changed from positive to negative by a relatively slight change in temperature. I have discovered that germanium is preeminently adapted to the purposes of the invention and I therefore claim the unique applications of this element hereinafter set forth.

In rectifying alternating current according to the present invention the temperature of the resistance element is varied in synchronism with the alternating current so that it offers greater resistance to the passage of alternating current during the positive half-cycles than during the negative half-cycles or vice versa. The temperature of the element may be varied directly by the alternating current or indirectly by an auxiliary source of heat whose frequency of application is synchronized with the alternating current; and the temperature of the element may be varied either by current flowing therethrough or by radiation or conduction.

For the purpose of illustrating the principles of the invention certain concrete embodiments have been illustrated in the accompanying drawings in which:—

Fig. 1 is a diagram of one embodiment:

Fig. 1^a is a diagram indicating the character of the resultant current in the embodiment shown in Fig. 1;

Fig. 2 is a diagram of another embodiment;

Fig. 2^a is a diagram illustrating the character of the current produced by the embodiment shown in Fig. 2;

Fig. 3 is a diagram showing the character of the resistance coefficient of germanium;

Fig. 4 is a diagrammatic illustration of another embodiment;

Fig. 4^a is a section on the line 4—4 of Fig. 4;

Fig. 4^b is a diagram indicating the character of the currents in the embodiment shown in Fig. 4;

Fig. 5 is a diagram of another embodiment;

Fig. 5^a is a diagram showing the character of the currents produced by the embodiment shown in Fig. 5 when the resistance element has a negative coefficient;

Fig. 5^b is a similar diagram showing the character of the currents in Fig. 5 when the resistance element has a positive coefficient; and

Fig. 6 illustrates an embodiment similar to that shown in Fig. 4.

The particular embodiment of the invention shown in Fig. 1 comprises a transformer T in the secondary of which is the resistance element G, the magnetized coil M and a load L. The resistance element G has a negative coefficient and is preferably formed of germanium. The magnetized coil M has a permanently magnetized core. By virtue of the magnetized coil M alternate half-cycles of current will be suppressed in the secondary so that, in the absence of the resistance element G, the current flowing in the secondary will be of the general character indicated by the curve H in Fig. 1^a, that is, the half-cycles above the base line will be relatively peaked and the half-cycles below the base line will be relatively flat. If the resistance element G has a resistance coefficient curve of the character shown in Fig. 3, its resistance will rapidly decrease when heated to a temperature beyond approximately 200° C. The elements of the circuit are so correlated that element G will not be heated to this temperature during the flat negative half-cycle current but will be heated to or above this temperature during the peaked positive half-cycles. Thus the resistance will drop to a relatively low value during the positive half-cycles and at such times the current in the secondary will rise to a relatively high value as indicated in a general way by the curve D of Fig. 1^a.

The system shown in Fig. 2 is similar to that shown in Fig. 1 except that a battery B is substituted for the magnetized coil M of Fig. 1. Obviously, this battery will oppose alternate half-cycles of the current, and assist the other half-cycles. Thus in Fig. 2^a

the current which would be produced by the battery alone is represented by the line B', the current which would be produced by the transformer T alone is represented by the line T', and the resultant current which would be produced in the absence of the resistance element G is represented by the line H. By properly co-ordinating the elements of the system the relatively large half-cycles of current (the positive half-cycles of curve H) may be caused to heat the resistance element G to the range where its coefficient is negative and the resultant current will therefore be of the general form represented by the curve D in Fig. 2^a.

The system shown in Fig. 4 comprises a resistance element G enclosed in a cooler A in the form of a water jacket and two auxiliary heating elements C which may take the form of semi-cylindrical plates of black platinum foil. The space within the cooler A is preferably filled with hydrogen or helium and sealed by means of walls E of suitable insulating material. The distances between the plates C and the element G as well as the distances between the plates C and the walls of the cooler A are preferably made as short as possible so as to make the transfer of heat between the parts as rapid as possible, the excellent conductivity of hydrogen or helium further increasing the rate of heat transfer. The resistance element G is connected to the secondary of transformer F in series with the load L and the plates C are connected to the secondary of a transformer I which also has a direct current winding $\bar{i}$, the primary of the transformer I being connected to the same alternating current source as the primary of the transformer F. Thus alternating current flows through the plates C from transformer I in synchronism with the current flowing through the resistance element G from the transformer F.

The direct current winding $\bar{i}$ on the transformer I causes the current flowing through the plate C to be unsymmetrical as indicated by the curve H in Fig. 4^b. Thus the resistance G is heated to a higher temperature during the positive half-cycles of current flowing through the resistance element G than during the negative half-cycles, thus varying the resistance of G as indicated by the curve R in Fig. 4^b. During the smaller negative half-cycles of current flow in the plates C heat is radiated from the element G to the plates and thence to the cooler A. Instead of this particular arrangement for alternately heating and cooling the element G any other suitable means may be employed. By properly correlating the various elements in this system the resistance element G may be heated to the point where its resistance coefficient becomes negative during positive half-cycles of current without

being heated to this temperature during the negative half-cycles, thereby to produce a current in the load circuit of the general character indicated at D in Fig. 4^b.

The system shown in Fig. 5 comprises the main transformer J and an auxiliary transformer K having their primaries connected in series to the source of alternating current with a variable resistance N or other suitable impedance in the circuit for adjusting the phase relationship between the two transformers. The secondary of the transformer J is connected in series with the variable resistance element G and the load L. The secondary of the transformer K is connected to opposite sides of the resistance G, preferably through a condenser O, and has a direct current winding P for rendering the secondary current unsymmetrical as above described in connection with Fig. 4. An inductance Q may be interposed between the resistance G and the secondary of transformer J to restrict the current from transformer K to the resistance element G. With this arrangement the resistance G is heated to different temperatures during alternate half-cycles of current from transformer J as a result of the unsymmetrical current produced by transformer K.

Fig. 5^a represents the character of the currents in the load circuit of Fig. 5 when the resistance element G has a negative coefficient, as for example when it is composed of germanium and when operating between say 100° C. and 400° C. The curve H represents the current caused to flow through resistance G by the transformer K; the curve R represents the varying resistance of the element G; and the curve D represents the current flowing through the load L from the transformer J as controlled by the variable resistance G, it being understood that the transformers J and K are suitably proportioned and suitably adjusted in phase relationship by the resistance M to produce a current of this character.

Fig. 5^b illustrates the character of the currents when the resistance element G has a positive coefficient, for example when employing germanium throughout the temperature range in which it has a positive coefficient, say 0° C. and 100° C. In this figure H represents the current produced in the resistance G by transformer K, R the varying resistance of the element G and D the resultant current in the load L.

The embodiment shown in Fig. 6 is similar to that shown in Fig. 4 and may be similarly employed. Instead of positioning the heating elements (C, C of Fig. 4) between the resistance element (G of Fig. 4) and the cooling element (A of Fig. 4) the resistance elements G' and G'' are located between the heating element C' and the cooling element A' which may be a metallic conductor. The

resistance elements G' and G'' may be in the form of thin ribbons of germanium (e. g. one mil thick) and mounted on A' by insulated screws. The heating element C' may comprise a ribbon of nickel similarly mounted. The three ribbons are preferably mounted under tension so as to be held taut, the supports preferably being resilient for the purpose. The heating and resistance elements may be connected in suitable circuits, as for example in Fig. 4, the resistance elements G' and G'' being connected in series or parallel or in separate circuits but preferably in parallel like elements C, C in Fig. 4; and as in Fig. 4 the various elements are also preferably enclosed and surrounded with a good heat conducting gas such as helium.

From the foregoing it will be evident that the temperature of the resistance element may be controlled in various ways and that, when using unsymmetrical alternating current, that the current may be made unsymmetrical in various ways. Thus in Fig. 1 a magnetized coil is employed for this purpose, in Fig. 2 the source of direct current B, and in Figs. 4 and 5 a direct current winding on the transformer which supplies the heating current.

It will be understood that the curves in Figs. 1^a, 2^a, 4^b, 5^a and 5^b are not intended to indicate exact values or relationships but merely the general relationships between the currents and resistance.

I claim:

1. An electrical system for modifying current comprising a circuit including an impedance element which is variable in response to temperature changes, and means for applying both half waves of a cyclically varying source of energy to said element for varying the temperature thereof and for automatically causing the temperature of said element to be different in alternate half cycles of the said waves, thereby to vary the current in the circuit in a corresponding manner.

2. An electrical system for modifying alternating current comprising a circuit including a resistance element having a negative temperature coefficient of resistance, and means for heating said element during both half cycles of the alternating current and for automatically heating said element to a higher temperature during the half-cycles to be utilized than during the half-cycles to be suppressed.

3. An electrical system of the character described comprising a circuit including an impedance element which is variable in response to temperature changes, means for transmitting both half cycles of an alternating current through the circuit, and means for varying the temperature of said element in synchronism with said alternating current,

whereby alternate half-cycles of the alternating current will be retarded in different degree by the element.

4. An electrical system of the character described comprising a circuit including an impedance element which is variable in response to temperature changes, means for transmitting both half waves of an alternating current through said circuit, and means for causing half-cycles of one sign to heat said impedance to a temperature different from its temperature during half-cycles of opposite sign whereby alternate half-cycles are opposed by the impedance in different degree.

5. An electrical system of the character described comprising a circuit including a resistance element having a negative temperature coefficient of resistance, means for impressing uninterrupted alternating current upon said circuit, and means for causing half-cycles of one sign to heat said resistance to a temperature higher than its temperature during half-cycles of opposite sign, whereby half-cycles of the first sign are affected by the resistance in lesser degree than half-cycles of the latter sign.

6. An electrical system of the character described comprising an impedance element having a positive temperature coefficient throughout one temperature range and a negative temperature coefficient throughout another temperature range, and means for periodically changing the temperature of the element from one range to the other range.

7. An electrical system comprising an alternating-current circuit including an impedance element having a positive temperature coefficient throughout one temperature range and a negative temperature coefficient throughout another temperature range, and means for changing the temperature of said element from one of said ranges to the other range during alternate half-cycles of current.

8. An electrical system comprising a circuit including an impedance element having positive and negative temperature coefficients throughout different temperature ranges respectively, means for impressing alternating current upon said circuit, and means for causing the alternating current to change the temperature of said element from one of said ranges to the other range during alternate half-cycles of said current.

9. An electrical system comprising an alternating-current circuit including a resistance element whose resistance decreases with increase of temperature throughout one temperature range but not throughout an adjoining range, means for maintaining the temperature of said element within the latter range during half-cycles of one sign, and means for changing the temperature to the first range during half-cycles of opposite sign.

10. An electrical system comprising a circuit including a resistance element whose resistance decreases with increase of temperature throughout one range but not
5 throughout the next adjacent lower range, means for impressing alternating current upon said circuit, and means cooperating with said means for bringing the temperature of said element within one of said
10 ranges during half-cycles of one sign and within the other range during half-cycles of opposite sign.

11. An electrical system for modifying current comprising a circuit including an
15 impedance element of germanium, and means for automatically varying the temperature of said element in a predetermined manner, thereby to vary the current in the circuit in a corresponding manner.

20 12. An electrical system for modifying alternating current comprising a circuit including a resistance element of germanium, and means for automatically heating said element to a higher temperature during the
25 half-cycles to be utilized than during the half-cycles to be suppressed.

13. An electrical system of the character described comprising a circuit including an
30 impedance element of germanium, means for supplying alternating current to the circuit, and means for varying the temperature of said element in synchronism with said alternating current, whereby alternate half-
35 cycles of the alternating current will be retarded in different degrees by the element.

14. An electrical system of the character described comprising a circuit including an
40 impedance element of germanium, means for impressing alternating current upon said circuit, and means for causing half-cycles of one sign to heat said impedance to a temperature different from its temperature during half-cycles of opposite sign whereby alternate half-cycles are opposed by the im-
45 pedance in different degree.

15. An electrical system of the character described comprising a circuit including a
50 resistance element of germanium, means for impressing alternating current upon said circuit, and means for causing half-cycles of one sign to heat said resistance to a temperature higher than its temperature during half-cycles of opposite sign, whereby
55 half-cycles of the first sign are affected by the resistance in lesser degree than half-cycles of the latter sign.

16. An electrical system of the character described comprising a germanium element having a positive temperature coefficient throughout one temperature range and a
60 negative temperature coefficient throughout another temperature range, and means for periodically changing the temperature of the element from one range to the other range.

17. An electrical system comprising an
65 alternating-current circuit including a germanium element having a positive temperature coefficient throughout one temperature range and a negative temperature coefficient throughout another temperature range, and
70 means for changing the temperature of said element from one of said ranges to the other range during alternate half-cycles of current.

18. An electrical system comprising a circuit including a germanium element having
75 positive and negative temperature coefficients throughout different temperature ranges respectively, means for impressing alternating current upon said circuit, and means for causing the alternating current to change the
80 temperature of said element from one of said ranges to the other range during alternate half-cycles of said current.

19. An electrical system comprising an alternating-current circuit including a ger-
85 manium element whose resistance decreases with increase of temperature throughout one temperature range but not throughout an adjoining range, means for maintaining the temperature of said element within the lat-
90 ter range during half-cycles of one sign, and means for changing the temperature to the first range during half-cycles of opposite sign.

20. An electrical system comprising a cir-
95 cuit including a germanium element whose resistance decreases with increase of temperature throughout one range but not throughout the next adjacent lower range, means for impressing alternating current
100 upon said circuit, and means cooperating with said means for bringing the temperature of said element within one of said ranges during half-cycles of one sign and within the other range during half-cycles of
105 opposite sign.

Signed by me this second day of May, 1923.

CHARLES G. SMITH.