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M. KALLMANN.

ELECTRIC CONTROLLING DEVICE.

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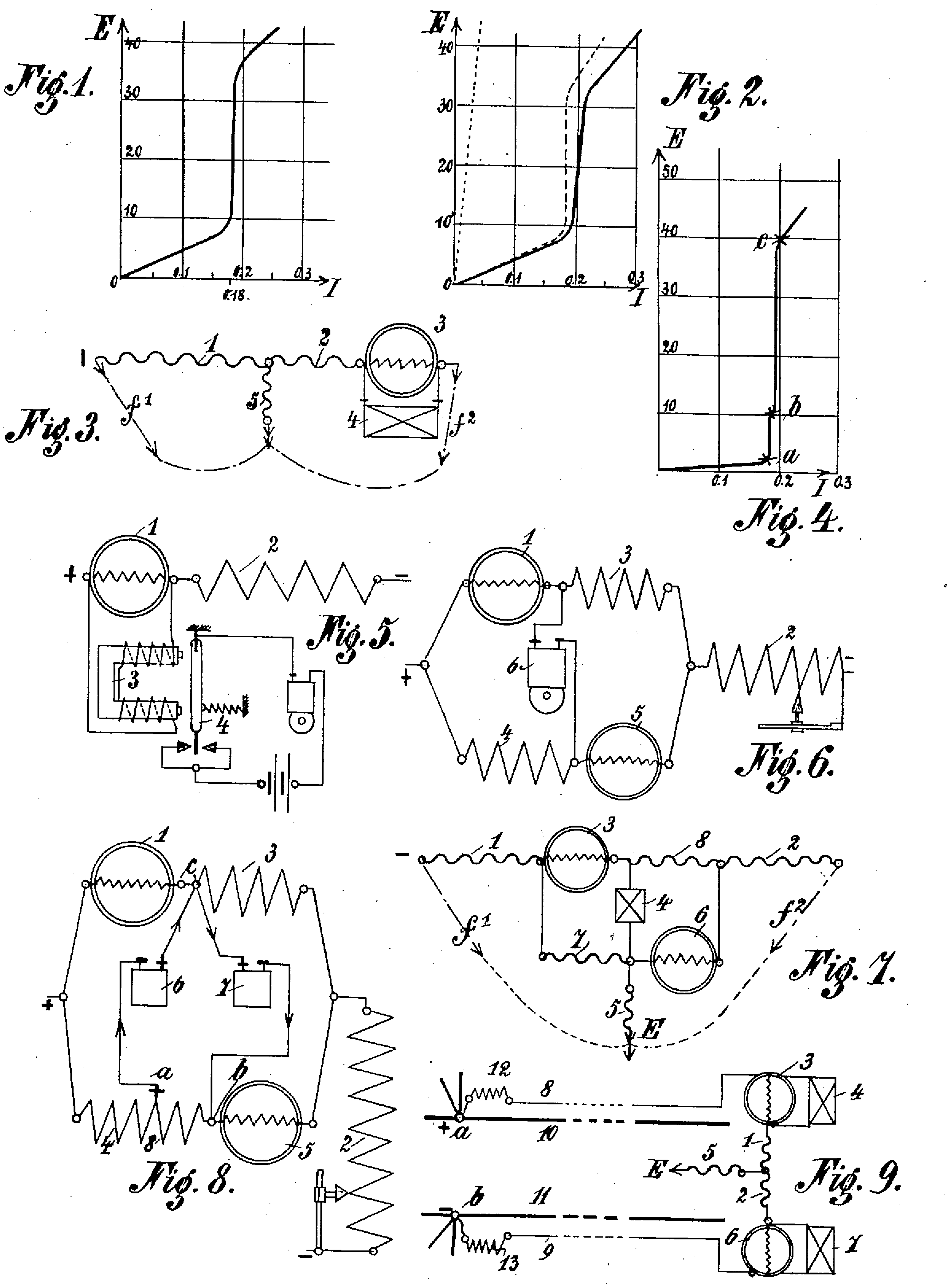

Witnesses:

J. M. Fowler Jr

Ralph J. Mitchell.

Inventor:

Martin Kallmann,

By Mason, Fenwick & Lawrence

Attys.

UNITED STATES PATENT OFFICE.

MARTIN KALLMANN, OF BERLIN, GERMANY.

ELECTRIC CONTROLLING DEVICE.

No. 862,740. Specification of Letters Patent. Patented Aug. 6, 1907.

Application filed June 1, 1905. Serial No. 263,313.

To all whom it may concern:

Be it known that I, MARTIN KALLMANN, engineer, of Berlin, Germany, Passauerstrasse 1, a subject of the German Emperor, have invented new and useful Improvements in Means for Signaling Variations of Pressure in Electric Conductors, of which the following is a specification.

This invention relates to improvements in methods for measuring, switching, signaling and regulating electric current, by means of which the sensitiveness is rendered many times greater than that obtained by the old processes with direct switching-in or branching off of constant shunts, this result being obtained by the use of resistances which change to a considerable extent within given limits and have the tendency to maintain the current passing through them almost exactly constant, in spite of wide fluctuations in the pressure or intensity in the circuit. This is effected by the use of metallic resistances of very high temperature coefficient, more particularly of very thin iron wire, for iron shows in the incandescent state, say at $t=850°$ C, a resistance ten times greater, and according to some, even eighteen times greater than the resistance when cold.

As shown by the presence of the square member, the property of considerably changing the resistance even on the slightest change of intensity of pressure becomes particularly pronounced at high temperatures, that is to say, from the darkest to the brightest red heat; I use therefore such automatic or, as I call them "variation resistances" or simply "variators" at those temperatures. In order to prevent oxidation and enable even the finest iron wire to be used at bright red heat, and its heat capacity, which is of great importance as regards the load on it, to be exactly regulated, this thin iron wire, preferably in the shape of spirals, as in the additional resistances for Nernst lamps, is arranged in an atmosphere of indifferent gases, preferably in hydrogen, on account of its great heat conductivity. Such resistances, calculated, say, for a load of 0.15 amp., maintain that current nearly constant, even when the pressure at their ends fluctuates between 10 and 40 volts. This socalled regulation field or limit of regulation of a variation resistance depends on its size, shape and heat capacity, for small falls in pressure, for instance, variation resistances of 3–10 volts or the like can be used, for larger, variators, of 20–50 volts and so on, the intensities of current used being between about 0.1 and about 2 amp. For greater intensities of current, several resistances are connected in parallel, for larger pressure differences, in series.

As an example, let a comparison of action be instituted between a constant shunt, say, of nickelin, and a variator. Assuming, for instance, that the pressure in a circuit is equal to 220 volts, and that a constant resistance of 100 ohm is connected in series with another constant resistance of 1122 ohm, then, in accordance with these 1222 ohm, the intensity of the current in the circuit is 0.18 amp. and the pressure at the 100 ohm resistance will be 18 volt, which is indicated by means of a voltmeter or the like. If the pressure changes to the extent, say, of 4.4 volt, that is to say, of 2%, to 224.4 volt, then the current in that constant circuit will rise to 0.1836 amp., and the pressure at the ends of the 100 ohm resistance to 18.36 volts. The sensitiveness is, therefore, very small, but it will be increased many times if, instead of a constant resistance of 100 ohm, a variation resistance according to this invention is introduced into the circuit, which then at 0.18 amp. would be in the medium incandescent state and would automatically maintain the current at that constant intensity by the changes of its own resistance for fluctuations of pressure between, say 10 and 30 volts. Then when the pressure in the circuit rises to 224.4 volt, this variation resistance must increase its resistance of 100 ohm, to which corresponds a pressure of 18 volts at its ends, to 124.4 ohm, while the additional resistance remains at 1122 ohm, in accordance with the unaltered 0.18 amp. The variation resistance reaches accordingly a higher state of incandescence and increases its resistance to the extent of 24.4%, so that the pressure at its ends will now be $124.4 \times 0.18 = 22.4$ volt, while the constant resistance still shows at its ends a pressure of $0.18 \times 1122 = 202$ volt The full increase of pressure in the circuit by 4.4 volt (from 220 to 224.4) measured in the absolute has thus taken place on the variation resistance only, at the ends of which the change thus produced in per cent even exceeds many times the total change of pressure viz. 22.4 against 18 volts, or an increase of 24.4%, that is to say, more than 12 times the total change of pressure in per cent (2%). The calculation shows therefore that, taken absolutely, the change of pressure produced takes place, theoretically, to the full extent, practically nearly to the full extent, in the variation resistance, although the latter forms only a small fraction of the total resistance (for instance 100 ohm compared to 1122 ohm), but the change expressed in per cent takes place with a sensitiveness increased nearly in the same ratio as that existing between the total resistance and the variation resistance. In this way the sensitiveness and precision of voltmeters, relays and electro-mechanical apparatus for any signaling, indicating and other purposes, (automatic cutouts, cell-switching devices, regulating resistances etc. and all measuring instruments) even in simple parallel connection, that is to say, with the shunt to the variation resistances can be made considerably greater than hitherto. As will be seen from the example, this advantage is the greater the smaller the variation resistance in proportion to the additional resistance, thus, for instance, the above mentioned variation resistance of 100 ohms and 10–30 volts regulating field, will act at a higher working pressure, that is to say, at 440 volts, much more advantageously than in installations with 110 volts, or the variation resistance is selected for a smaller regulating field, for instance, for 3–10 volts, for such small working pressures. Such a resistance for 3–10 volts in a 440 volt circuit would, however, if it normally absorbs a pressure of 4.4 volts at 440 volts, show already 100% pressure variation (from 4.4 to 8.8 volts) at its ends with an increase of the working pressure by 4.4 volts that is to say by 1% (444.4 volts). It is, therefore, characteristic for such use of variation resistances that they merely form a small fraction of the total resistance. The greater part is constituted by a constant or "energy consuming" resistance (for instance, 1122 ohm) and it will be seen that at the latter additional resistance the pressure is always

$$0.18 \times 1122 = 202 \text{ volts}$$

in spite of the fluctuations of the circuit pressure, while at the lowest pressure of 210 volts, the pressure at the variation resistance will be 8 volts, and at the highest pressure of 230 volts, 28 volts.

Figure 1 is a diagram of the curve of the variation resistance the abscissæ representing the intensity, and the ordinates the pressure. Fig. 2 is a diagram of the curve when constant shunt resistance is introduced in parallel in the circuit, the curved dotted line showing the variation resistance, the straight dotted line the current in shunt and the full line the current in the common circuit. Fig. 3 is a diagrammatic view of one arrangement of the invention to indicate insulation defects. Fig. 4 is a diagram of the curve of the variation resistance when two different variation resistances are connected in series, one variation resistance having a regulatory range from point *a* to *b*, the other part *b* to *c*, the abscissa indicating the current passing through the series. Fig. 5 is a diagrammatic view of one manner of employing the parallel or series connections of the constant or variation resistance. Fig. 6 is a diagrammatic view of the invention employing a Wheatstone bridge and with the variation resistances in the opposite branches of the bridge. Fig. 7 is a diagrammatic view of a modified arrangement employing simultaneous differential connections for the control of the pressure and determining insulation defects. Fig. 8 is a diagrammatic view of an unsymmetrical bridge designed to be used instead of that shown in Fig. 7. Fig. 9 is a diagrammatic view of one of the numerous applications of the present invention.

Fig. 1 shows a curve of such variation resistances, the abscissæ representing the intensity of the current I, and the ordinates the pressure E at its ends. According to this example, the current remains constant, or 0.18 amp., between pressures of 10 to 30 volts while with insufficiently heated resistance it remains below that figure; in this latter field the pressures are 0 to 10 volt above the regulating limit—30 to 40 volts. After bright red heat has been reached (at about 30 volt), the variation resistances show only very little change, so that an increase of current takes place in them as in other moderately constant resistances. As a rule, the pressures outside the regulating field are not used. The position is slightly changed, when a constant resistance, such for instance as a relay, electro-magnet and the like, is connected to the variation resistance. The shape of the curve will then be that shown in Fig. 2, the current increasing with the increase of pressure to the extent of the value of the shunt current. If the resistance of the said shunt in the above mentioned example be, say, 1500 ohm, then, with a pressure of 30 volts, the intensity of current in the shunt will be 0.02 and with a pressure of 10 volts, 0.0066 amp. This example is shown in Fig. 2, the inclined dotted straight line showing the current in the shunt, the chain curve the current in the variation resistance, and the full line curve the two currents together, as they appear in the common additional resistance.

As will be seen the current increases within the regulating field (10 to 30 volts) with the increase of pressure, and the sensitiveness is slightly reduced, for if, for instance, the above mentioned 1500 ohms represented the resistance of a measuring instrument (relay and the like), then, in the initial example, the pressure at the variator would be only 10.3 for the normal pressure, and for a total increase of pressure of 4.4 volts, about 12.8 volts, that is to say, 2.5 volts increase in the variator pressure, that is to say $\frac{2.5}{4.4}$=about 56% of the total change. Generally speaking, therefore, in order to avoid excessive reduction of sensitiveness, the resistance of relays and the like must be made as large as possible. The reduction of sensitiveness is due to the change of the intensity of the current, as the additional resistance now absorbs further pressure corresponding to the change of shunt current. The following formula gives the pressure *e* at the ends of the variation resistance:

$$e = \frac{E - W.\,i}{1 + \frac{W}{x}}$$

e being the resulting variation pressure, E the total working pressure (say, 220 volts). W the non-divided additional resistance (say 1122 ohms). *i* the constant current (say 0.18 amp.) in the variation resistance, and *x* the resistance of the shunt (say, 1500 ohms). This shunting offers, however, the advantage that the variation resistance is protected against overloading and destruction even with a narrow regulating field, say 3 to 12 volts, that is to say, with a small value of the variation resistance, but even with great fluctuations of the working pressure, for instance, of over 20 volts, for the intensity of current rises in accordance with the pressure of the curve in Fig. 2, and therefore a portion of the fluctuations of the pressure is taken up by the additional resistance. Connection of artificial resistances or even of the ordinary resistances of measuring apparatus and so on, in parallel with the variator, represents therefore a measure of self-protection. To a certain extent this self-protection is attained by the undivided variation resistance arrangement shown in Fig. 1, for the curve shows, beyond, for instance, 30 volts, an increase of current nearly to the maximum of 2.1 amp., so that pressure absorption thus produced in the large additional resistance also limits the overload on the variation resistance in the event of a great increase of pressure, and represents a self-protection, which, expressed in per cent, is the greater, the smaller the variation resistance compared to the total resistance.

The curve in Fig. 2 shows already considerable influence even of a high shunt on the degree of incandescence assumed by the variation resistance, or on the amount of pressure appearing on it, so that such variation resistances are at the same time very sensitive, even in case of very large shunt resistances such as those occurring through insulation defects and earth connection. If, for instance, the variation resistance which normally absorbs 18 volts at a current of 0.18 amp., receives a shunt $x=1000$ ohms, then, in this case, the pressure at the ends of the variation resistance would sink from 18 to 8.5 volts, as the additional resistance of 1122 ohms now destroys 211.5 volts, instead of 202 volts, as before. For indicating insulation faults, the circuit would generally be earthed in the center, as shown in Fig. 3; this would mean, in the case under consideration, at 611 ohms ($=\frac{1122}{2}$ ohms without shunting to the variation resistance). On one half there is fixed resistance of, say, 611 ohms, on the other half a variation resistance of, on the average, 100 ohms, which normally absorbs 18 volts, and in front of it is also switched a constant resistance of about 511 ohms. In the event of an earth connection of, say, 10.000 ohms, taking place, the pressure at the ends of the variation resistance, (for instance, at a voltmeter, relay or the like) would, in accordance with the above-mentioned formula, fall from the normal value 18 to 11.7, that is to say, an earth connection of even 10.000 ohms insulation resistance would produce a variation of pressure of about 6.3 volts, or about 35%, since, as experiment and calculation show, this shunt of 10.000 ohms to the circuit, causes the valve of the variation resistance, on account of the decrease in the degree of incandescence, to fall from the former from about 100 ohms to about 65 ohms. With an ordinary constant resistance of 100 ohms in place of the variator, only about 2%, viz. 0.4 volt pressure fluctuation, would be obtained at its ends or at the branched-off measuring instrument. This shows the great sensitiveness of the variators even for indicating shunt-insulation or earth-connection.

In Fig. 3 on the one side of the earth connection, the constant resistance 1 is made as great as the sum of the constant resistance 2 and of the variation resistance 3, to which is connected a relay 4. Moreover, as protection against excessive pressure at the positive pole, a protective resistance 5 of, say, a few hundred ohms, is shunted to earth E. Insulation defects are indicated by f' and f^2. In practice this connection can be made double ended and symmetrical on both sides of the earth connection, by the combination of a constant and of a variation resistance. The relay 4 shows both pressure fluctuations like a signal voltmeter and the like, and insulation defects, and is very sensitive The indicating device 4 can be used to actuate not only measuring apparatus, but also signaling devices, lamps, automatic cut-outs, automatic cell-switching devices, regulators, etc. In order to protect variation resistances against over-load and destruction without materially affecting their sensitiveness, in such shunt connection branching off from the variation resistances and in the case of very great fluctuations of pressure or earth connection, the phenomenon shown in Fig. 4 can be advantageously utilized. This phenomenon is based on the connection in series of two or more variation resistances differing very little in their heat capacity and size. If, for instance, a variation resistance for 0.18 amp., the regulating field of which is situated between 3 and 10 volts interval a-b of the pressure curve Fig. 4, is switched in series with a second variation resistance which, at about 0.2 amp., in accordance with its size, length etc., has a regulating field of 10—40 volts (b—c of the curve) then, with normal pressure fluctuations of, for instance, 3 volts, only the first small resistance would act as a buffer and at the exact intensity of current of 0.18 amp. would absorb this fluctuation of 3 volts almost completely and cause it to act on an apparatus connected to it in parallel. Only when the pressure fluctuation becomes greater, the pressure increasing say by 20 volts, the second larger variation resistance (b to c) will become operative, as it also will become incandescent, the intensity of the current having increased about 0.2 amp. Within the normal regulation limits, only the smaller variation resistance used for the indicating device, becomes therefore incandescent, the second one becoming heated only to a very small extent; in the event of greater irregularities which as a rule need not be indicated, the second resistance, by its subsequent increase of resistance, takes up the fluctuation, and acts as a protector by preventing excessive increase of current.

A simple shunt connection, for which the before mentioned parallel or series connection of constant or variation resistances of a given capacity could be used, is diagrammatically illustrated in Fig. 5. In this example, a variation resistance 1, or an already described combination of such is connected in series with an additional resistance 2 between the poles; in shunt circuit to 1 is arranged a relay or the like 3, and when certain limits are exceeded to either side, for instance, when the working pressure changes to the extent of 1% the armature 4 is attracted with great force, and a signaling device, switching apparatus or the like operated. The setting for the normal state, (for instance, 220 volts) is effected by means of the additional resistance 2, and the sensitiveness can be regulated by means of the spring of the armature 4. If, instead of the constant resistance 2 in Fig. 5, we assume a load on the circuit, for instance, incandescent lamps, motors or the like, then, with a suitably calculated variation resistance 1, instead of a pressure relay, a current relay will be produced, that is to say, an automatic current cut-out which, when a certain intensity of current has been exceeded, releases switches or reversing switches, indicating devices or signaling apparatus (such as signal lamps). In accordance with the pressure curve, when the current exceeds certain limits, the increase of pressure by jumps or jerks at the ends of the variation resistance which is in shunt on the relay, would operate the latter in an energetic manner. In place of the simple shunt connection, it is possible also to use a differential measuring method on the system of a differential galvanometer, that is to say, with two differentially connected windings on the rela or measuring apparatus, or on the same system as the Wheatstone bridge.

As already stated, the pressure in a constant resistance switched in front of a variation resistance, is almost exactly constant within the limits of the regulation field. A differential method based on the comparison of this constant pressure with the varying variator pressure, can be called a "compensating method" of a new kind; for the constant pressure in the normal resistance acts here in the same way as the normal element in the compensator, owing to the current being automatically maintained constant like the electromotive force serving for comparison.

The connection on the Wheatstone bridge system is shown in Fig. 6. In that figure the variation resistances 1 + 5 are in the opposite bridge branches, 3 and 4 are constant comparative resistances which, for the sake of simplicity, are either of the same size as the variation resistances, or the ratio between them is given one, the relay and a signaling device 6 are in the bridge and 2 is the adjustable additional resistance which takes up by far the greatest portion of the pressure between + and —, for instance, in installations with 220 volts, about 200 volts. When the pressure is normal, the alarm 6 remains at rest in the bridge 6, but, in the event of the pressure changing even to the extent of 1 volt, it would sound the alarm, which will be the louder, the greater the fault; for instance, it would be exceedingly loud at 210 or 230 volts, as nearly the whole amount of the fault, say 10 volts, would become operative in it. By such differential connection, faults of pressure are indicated directly in an absolute measure, and with a sensitiveness that is the greater, the greater the resistance of the bridge 6, as will easily be understood by calculating the current in the branches.

In the arrangement in Fig. 6 the working pressure is shown direct, that is to say, without an auxiliary source of current, as means for operating an alarm 6; in this way it is rendered possible to find out the magnitude of the fault by the loudness of the alarm signal. Of course, instead of this, the signaling itself could be effected by means of a relay arranged in the bridge, the said relay operating, as shown in Fig. 5, a separate circuit with battery, signaling or other apparatus or switches, it being then possible to distinguish whether it is a question of an excessively high or excessively low pressure or the like.

In the event of the simultaneous use of differential connection for the control of the pressure and of the insulation of the circuit, the arrangement can be supplemented as shown in Fig. 7, in which 4 is the relay apparatus arranged in the bridge, 5 a protective resistance, immaterial for the working, 7 and 8 the comparative resistances, 3 and 6 variation resistances in opposite bridge branches, 1 and 2 halves of the additional resistance, preferably symmetrically divided between the two halves of the circuit. 1 and 2 in Fig. 7 correspond therefore to the simple additional resistance 2 in Fig. 6.

Instead of symmetric bridge—or differential—connection, Fig. 8 shows a disturbed or unsymmetrical bridge, in which 1 and 5 are variation resistance, and 6 and 7 are now two bridges instead of the former simple bridge, the bridge 6 being placed between c and a, and the bridge 7 between c and b; between a and b is arranged a small resistance 8 which is also used for "starting" or for initial exciting. The action is indicated by the current arrows. When, for instance, the pressure is normal, the potential at a is permanently higher than the potential at c by 2 volts, and the potential of b is to the same extent lower than that at c. A weak current will therefore pass through the electro magnets 6 and 7 even when the pressure in the circuit is in the normal state, the said current overcoming the inertia and the like of this apparatus, that is to say, providing a kind of starting momentum for the purpose of the easier starting, that is to say, of greater sensitiveness. If this pressure is increased by, say, only $\frac{1}{4}$ volt, then, as the "dead" position has already been overcome, the alarm device 6 will be operated and the pressure on it increased from, say, 2 to $2\frac{1}{4}$ volts, while 7 will remain at rest, as its pressure will sink to the extent of $\frac{1}{4}$ volt, that is to say, to $\frac{3}{4}$ volt, for the potential at b will have risen to the extent of $\frac{1}{4}$ volt, that is to say, in opposition to the initial fall of potential between c and b. Conversely, when the pressure falls, the apparatus 7 would give a signal of alarm, and the apparatus 6 remain at rest, as then the fall of pressure is supported, and at 6 reduced. Within certain, sufficiently wide limits, such an unsymmetric or double bridge acts, therefore as a means for operating, indicating, switching, measuring and regulating apparatus with any desired sensitiveness and precision, all moments or inertia which usually oppose the starting of all large apparatus, electro-magnetic relays, motors, etc. being overcome.

Of the numerous ways in which the combination of constant and variation resistances can be used, may be mentioned the application shown in Fig. 9, for indicating pressure and insulation defects in circuits. For the sake of simplicity, only one feed line of a three-wire circuit is indicated by the cable cores 10 and 11, a and b indicating the positive and the negative poles of the feeding center; at that point, that is to say, mostly in a distribution box, two generally equal resistances 12 and 13, which, for the sake of simplicity may be each constituted by an incandescent lamp, are switched at the corresponding poles into the circuit of the test wires 8 and 9. At the station these testing wires 8 and 9 each contain one variation resistance 3 and 6, and one additional resistance 1 and 2. The center is earthed through the protective resistance 5 (in the case of three-wire circuit, also the neutral pole). The remaining test wires are fitted out in the same way each of them being connected to one variation resistance and one relay (4 and 7).

The working is the same as in the cases already described, the relays becoming operative as soon as the pressure at the respective feeding centers becomes greater or smaller than a certain definite value. They act then as a single pressure control; the center of the relay pressures connected together at a common apparatus, indicating the medium pressure. Each insulation defect between the test wire and the earth, as well as between the test wire and the cable core is further indicated at the corresponding relay. If, for instance, in Fig. 9, a connection to earth is made from the test wire 8, even if there still be a resistance of several hundred ohms between it and the earth E, the relay 4 will give a signal, as the pressure in it will fall. This also takes place in the event of an interruption of a test wire on account of some disturbance, more particularly when, through an injury to the cable, or owing to the penetration of moisture etc: into the cable cores, the test wires of which in the distributing circuit are connected radially to the test wires of the corresponding feed circuit, the test wire makes direct contact or receives only a small insulation resistance compared to the cable core of the same polarity; for then the additional resistance 12 or 13 will be entirely or partly short-circuited by this defect, and the pressure would in such case rise in the corresponding relay 4 or 7. A contact between test wire and cable core acts therefore as an excessive working pressure. In this way all kinds of defects in the networks are automatically signaled and their position indicated, because the test-wires are connected only in each district. Great differences of pressure between the test wire and the corresponding cable core are at the same time avoided, without the intensity of the current in the testing-wires changing, as the variators absorb these fluctuations, and all irregularities are indicated in a very sensitive manner at the relays or indicating devices etc.

Similarly to the former figures, instead of the shunt method, the method of differential connection preferably in the manner of Wheatstone bridge can be used, the above mentioned resistance being connected to the beginning (at the feeding center) of each test wire, while to the end (at the station) are connected two variation—and two constant—resistances in opposite branches, further a relay in the bridge, as well as the already mentioned "additional" resistance in front of the other pole.

It will be clear from the foregoing that by the use of variation resistances consisting of metal, more particularly of iron with such a high temperature coefficient that within certain "regulating fields" a nearly absolutely constant current is maintained, the said resistances absorbing only a small portion of the working pressure, the sensitiveness, both as regards indications of fluctuations of pressure and of the intensity of current and earth connections etc. can be made many times greater than that obtained by methods hitherto used, owing to the change in the variation resistance itself. These devices can actuate other apparatus with great precision and force, nearly the whole of these variation resistances being utilized, owing to the use of the differential connection which in its character resembles the compensation method for the purposes of indicating and of operating any desired devices. The property of these variation resistances, to require a certain time for their working depending on their heat capacity, can be utilized as a buffer or cushioning or deadening purposes, or it can be made use of for the purpose of avoiding notification of merely instantaneous and unimportant defects of insulation. There is also the advantage that by this shunt or differential method only comparatively small pressures are produced at the measuring instruments and the like, thus, for instance, in 500 volt installations, in connection to the variation resistance, only 10—50 volts, so that their manipulation is much easier, and the "additional" resistances which otherwise are required for apparatus for high pressures, for instance, for voltmeters, can be done away with, as is explained by the principle of the method described for these devices.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In an electric controlling device, a constant resistance, and a variation resistance connected in series with the constant resistance, and having a high temperature co-efficient, and which becomes incandescent in a variable degree by changes of potential absorbing but a comparatively small fraction of the working pressure, and an indicating device connected in shunt with the variation resistance.

2. In an electric controlling device, a branched circuit, each branch having a constant resistance, a variation resistance connected in series with constant resistance, other resistance before the branch absorbing the greater portion of the working pressure, the said variation resistance having a high temperature co-efficient and adapted to become incandescent in a variable degree by changes of potential, and a bridge connecting the branches at the opposite ends of the variation resistance and containing an indicating device.

3. In an electric controlling device, a branched circuit, each branch having a constant resistance connected in series with a variation resistance, a constant resistance before the branching absorbing the greater portion of the working pressure, the variation resistance having a high temperature co-efficient capable of becoming incandescent by the passage of a current, and a bridge connecting the branches at opposite ends of the variation resistance and containing indicating means acted upon by all the changes of potential.

4. An electric controlling device comprising a constant resistance, a variation resistance connected in series with the constant resistance, said variation resistance composed of thin iron wires contained in a hermetically sealed receptacle and surrounded by a non-oxidizing gas, and connected in series with the working pressure, and an indicating device connected in shunt with the variation resistance, and acted upon by the changes of potential.

5. An electric controlling device comprising a branched circuit, each branch provided with a constant resistance connected in series with a variation resistance, a variable resistance before the branching arranged to absorb the greater portion of the working pressure, the variation resistance having a high temperature co-efficient capable of becoming incandescent by the passage of a current, and a bridge connecting the branches at opposite ends of the variation resistance and containing an indicating device acted upon by all the changes of potential.

6. An electric controlling device comprising a branched circuit, each branch provided with a constant resistance, a variation resistance connected in series with each constant resistance, and an adjustable resistance before the branching positioned to absorb the greater portion of the working pressure, the said variation resistance having a high temperature co-efficient arranged to become incandescent in a varying degree by the changes of potential, a bridge connecting the branches at opposite ends of the variation resistances, and an indicating device located in the bridge.

In testimony whereof, I have signed my name to this specification, in the presence of two subscribing witnesses.

MARTIN KALLMANN.

Witnesses:
HENRY HASPER,
WOLDEMAR HAUPT.