

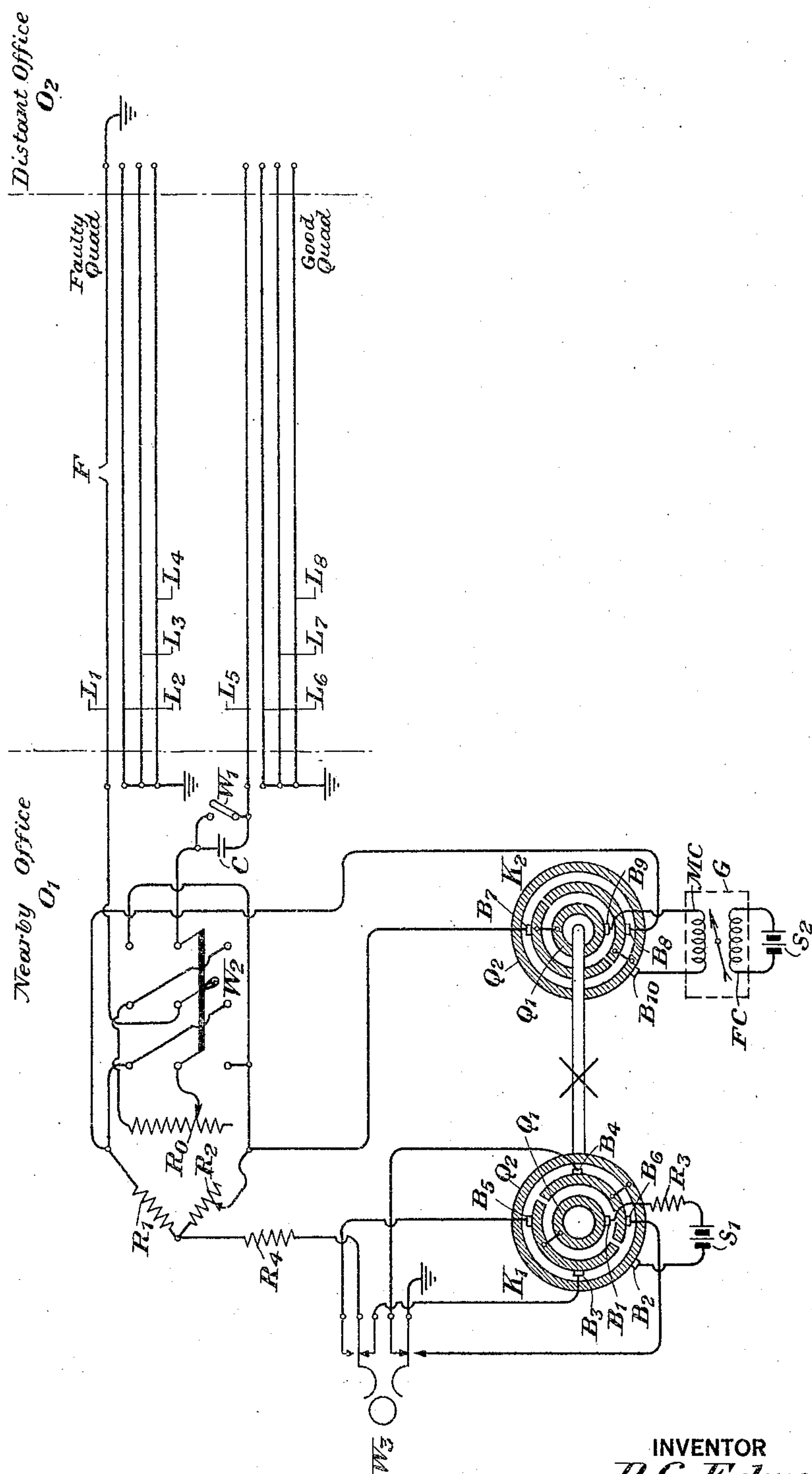
Dec. 6, 1932.

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1,889,824

TESTING SYSTEM

Filed Dec. 30, 1931



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TESTING SYSTEM

Application filed December 30, 1931. Serial No. 583,989.

This invention relates generally to electrical testing systems. More particularly, this invention relates to arrangements for locating an open circuit in one of the conductors of a telephone or other cable. Still more particularly, this invention relates to arrangements for eliminating such inductive interference as may affect and introduce error into the proper determination of the location of the fault in one of the conductors of the cable.

Heretofore, it has been possible to locate a fault in one of the conductors of a telephone line in a cable, by connecting that line as one of the arms of a Wheatstone bridge arrangement, a diagonal of which was supplied with pulsating current of reversible polarity, the other diagonal of which was connected to a galvanometer. However, currents induced into the Wheatstone bridge arrangement from extraneous sources such as grounded telephone circuits and other circuits or systems transmitting currents, interfered with the accurate location of the fault because these extraneous sources caused the pointer of the galvanometer to fluctuate over a very wide range.

Therefore, one of the objects of this invention is to provide arrangements for determining accurately the location of a fault in the conductor of a cable while at the same time eliminating the effect of extraneously induced currents.

Another of the objects of this invention consists in the provision of apparatus for the continuous application of alternating current of low frequency to one diagonal of a Wheatstone bridge arrangement, one of the arms of which includes a faulty conductor, including apparatus for deriving from the other diagonal of the bridge a steady direct current whereby the location of the fault may be accurately determined without interference from currents of induction.

While this invention will be pointed out with particularity in the appended claims, the invention itself both as to its further objects and features may be better understood from the detailed description hereinafter following when read in connection with the

accompanying drawing, showing one embodiment of the invention merely for the purpose of illustration.

Referring to the drawing, the reference character L_1 designates a conductor extending between a nearby office O_1 and a distant office O_2 . This conductor may have a fault designated F , some distance from the nearby office O_1 . This fault may be caused, for example, by a poorly soldered connection, by the careless joining of one part of the conductor with the other, or by any other form of disconnection. A bridge arrangement to be subsequently described, will be employed to determine the location of the resistive fault F , as well as to compare the capacitance of that conductor with the capacitance of a good conductor.

The reference characters L_2 , L_3 and L_4 represent three other conductors in the same quad as conductor L_1 , and these conductors also extend between the offices O_1 and O_2 . The conductor L_2 may be the mate of the conductor L_1 , and the conductors L_3 and L_4 may be considered as the other pair of the quad. The conductors L_2 , L_3 and L_4 are connected together at the nearby measuring office O_1 , and they are jointly grounded. At the distant office O_2 the conductor L_1 is grounded.

The conductors L_5 , L_6 , L_7 and L_8 represent the four conductors forming another quad of the same cable, all of which are in good condition. The conductors L_6 , L_7 and L_8 are connected together at the nearby office O_1 and these are all grounded. The conductor L_5 is arranged in one of the arms of the bridge arrangement which is adjacent to the arm including the faulty conductor L_1 . The various conductors of the two quads are set up so that the capacitance conditions will be as uniform as possible.

The conductor L_5 is in series with a single pole switch W_1 and the switch W_1 is shunted by a condenser C . A variable resistance R_0 is connected to a triple pole, double throw switch W_2 which has reversing features designed to permit the resistance R_0 to be connected either to the upper arm of the bridge which includes the faulty conductor L_1 , or to the lower arm of the bridge which includes

the good conductor L_5 . The fixed resistance R_1 and the variable resistance R_2 form the two ratio arms of the bridge arrangement.

The source of excitation of the bridge arrangement is connected to one of its diagonals through a commutator K_1 and a phase shift key W_3 . The commutator K_1 is associated with motor driven apparatus (motor not shown). The current derived from the other diagonal of the bridge arrangement is transmitted to a galvanometer G through another commutator K_2 . The commutators K_1 and K_2 are mechanically coupled to one another in any well known manner, and they are revolved at the same speed, preferably a low speed such, for example, as four revolutions per second.

Each commutator has two segments designated P_1 and P_2 , and two slip rings designated Q_1 and Q_2 , the segment P_1 being connected to the slip ring Q_1 , and the segment P_2 being connected to the slip ring Q_2 . Brushes B_1 and B_2 are associated with the slip rings Q_1 and Q_2 of the commutator K_1 , respectively. The brushes B_3 and B_4 are associated alternately with the segments P_1 and P_2 of the commutator K_1 . Similarly, the brushes B_5 and B_6 are associated alternately with the segments P_1 and P_2 .

The brushes B_1 and B_2 may be considered as the input brushes of commutator K_1 , and these are connected in a series circuit formed by a battery S_1 and a resistance R_3 . The brushes B_3 and B_4 , and the brushes B_5 and B_6 may be considered as different pairs of output brushes which are displaced 90 degrees from each other. The phase shift key W_3 normally connects the brushes B_3 and B_4 to one of the diagonals of the bridge arrangement, and when this key is operated the brushes B_3 and B_4 become disconnected and are replaced by the brushes B_5 and B_6 .

The brushes B_7 and B_8 are the input brushes of the commutator K_2 . These brushes receive current from another diagonal of the bridge arrangement and this current is impressed alternately upon the segments P_1 and P_2 of commutator K_2 . The brushes B_9 and B_{10} are associated with the slip rings Q_1 and Q_2 of commutator K_2 , respectively, and these brushes form the output pair. The latter pair of brushes impress unidirectional current upon the moving coil MC of the galvanometer G . The fixed coil FC of this galvanometer is connected to a battery S_2 .

The battery designated S_1 , by virtue of its connection to the input brushes B_1 and B_2 of commutator K_1 , provides an alternating potential for one of the diagonals of the bridge arrangement. The alternating potential is transmitted through the phase shift key W_3 and the protective resistance R_4 . The frequency of the potential applied to this diagonal of the bridge arrangement will be equal to the number of revolutions per second

made by the commutating apparatus. Thus, if the commutating apparatus makes four revolutions per second, the potential applied to the diagonal of the bridge arrangement will be reversed four times each second.

The moving coil MC and the fixed coil FC of the galvanometer G , are mutually reactive. By virtue of the connection of the fixed coil FC to the battery S_2 a steady magnetic field is provided for the galvanometer. However, a permanently magnetized element may, if desired, be substituted for the fixed coil FC and the battery S_2 .

To determine the location of the fault F in the conductor L_1 , switch W_2 is moved to its lower position so as to place the rheostat R_0 in series with the conductor L_5 . At the same time switch W_1 is opened. The phase shift key W_3 is retained in its normal position. The resistance of the rheostat R_0 is reduced to zero. The rheostat R_2 is adjusted so as to bring the pointer of the galvanometer G quite close to its central position. Then the phase shift key W_3 is operated so as to change the phase of the potential applied to the bridge by 90°. The rheostat R_0 may now be adjusted until the pointer of the galvanometer G is again close to its central position.

The rheostats R_0 and R_2 should be balanced several times with the phase shift key W_3 in its corresponding positions abovementioned. The pointer of the galvanometer G will finally remain quite fixed at its mid position even while the phase shift key W_3 is operated and released several times. The magnitude of the resistance R_2 is then recorded.

Another of the conductors within the same quad as the conductor L_1 as, for example, the conductor L_2 , will then be substituted for the conductor L_1 , and the various steps outlined hereinabove will be repeated so as to obtain a different value of resistance at the rheostat R_2 for a balanced condition in the bridge arrangement. The ratio of the first value of the resistance of rheostat R_2 obtained when the conductor L_1 was connected to the bridge arrangement, to the second value of the resistance of the rheostat R_2 obtained when a conductor such as L_2 was connected to the bridge arrangement, will represent the percentage distance from the nearby office O_1 to the fault F.

If the fault F is too close to the nearby office O_1 , then it will be impossible to bring the pointer of the galvanometer G near its mid position by the adjustment of the resistance of rheostat R_0 . In that event the switch W_2 will be moved to its upper position so as to place the rheostat R_0 in the upper arm of the bridge arrangement. The proper adjustment of the rheostat R_0 will then permit the operator to readily bring the pointer of the galvanometer G to its mid position,

unless the fault F is at or extremely close to the nearby office O_1 .

Some of the principles underlying this invention whereby the effect of currents induced from extraneous sources is prevented from affecting the measurements for the determination of a fault in a conductor, will now be explained.

The capacitance of a cable conductor such as L_1 is proportional to its length and this capacitance will be greater as the conductor is longer. In this invention the capacitance to ground of the conductor L_1 is first obtained, and then another conductor such as L_2 is substituted for the conductor L_1 , and the capacitance to ground of the conductor L_2 is measured. The ratio of these capacitances will represent the percentage distance to the fault, provided there are no currents induced into the measuring apparatus from extraneous sources.

But, in considering the effect of induced interfering currents it will be necessary to further analyze the apparatus involved in this invention. A conductor such as L_1 or L_5 , for example, may be assumed as the equivalent of a resistance component in series with a capacitance component. Each conductor may be considered as a generator of an interfering potential. Each of the generators simulating conductors L_1 and L_5 may be considered as having a low reactance and a resistance proportional to its length. These resistances are merely the resistive components of the impedances of the conductors. The condenser C which is in series with the conductor L_5 in the arrangement shown in the drawing, may be neglected because of its comparatively low reactance at the frequencies involved in the tests. It is a fact, determined by experiment, that the same electromotive forces are generated in a short conductor as in a long conductor. The only apparent difference between the effect of a short conductor and that of a long one, so far as interfering potentials are concerned, lies merely in its resistive component. In other words, the action of the apparatus of this invention is the same as if a single electromotive force supplied current through the resistive components of the good and bad conductors L_1 and L_5 , respectively, to the bridge arrangement, this electromotive force being, of course, in the diagonal of the bridge arrangement which supplies energy thereto. Since the bridge arrangement may be balanced for the alternating potential applied thereto by the commutating apparatus K_1 , it may also be balanced for the interfering potential.

It will be apparent that the condenser C is grounded through the capacitance of the good conductor L_5 rather than directly. The effect of this series arrangement is to reduce the capacitance somewhat below that of the condenser C and to add the resistive compo-

nent of the conductor L_5 . Thus, if the condenser C be assumed to be a one microfarad capacity, then a 50 mile No. 19 gauge non-loaded line would reduce the capacitance from one microfarad to about 0.85 microfarads, and the added resistance would be about 700 ohms.

There is a decided advantage in having the conductor L_5 in series with the condenser C . In this arrangement the flutter of the pointer of the galvanometer which is caused by extraneously induced currents, is considerably reduced because the two quads of conductors connected to the bridge arrangement are in the same cable and preferably in the same group of quads. Induced voltages have substantially the same effect on all of the conductors of the two quads, and the bridge arrangement may be much more easily balanced under these conditions than it would be if the condenser C were directly grounded.

The switch W_1 is shown in shunt with condenser C . The condenser C may be short-circuited by this switch if it is desired to compare the capacitances of the conductors L_1 and L_5 directly.

While this invention has been shown and described in certain arrangements merely for the purpose of illustration, it will be understood that this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. Apparatus for determining the location of a fault in a conductor and avoiding the effect of interfering potentials on the apparatus, comprising a Wheatstone bridge arrangement including the faulty conductor as one of its arms, a good conductor connected as another of its arms, a rheostat, means for connecting said rheostat in series with either of said arms, a source of alternating potential connected to one of the diagonals of the Wheatstone bridge arrangement, means for changing the phase of said alternating potential by 90 degrees, and means responsive to the alternating potential derived from the other diagonal of the bridge arrangement to determine whether the bridge arrangement is balanced.

2. Apparatus for determining the location of a fault in a conductor including a Wheatstone bridge arrangement, the faulty conductor being connected as one of the arms of the Wheatstone bridge arrangement, a good conductor, a condenser connected in series with the good conductor as another of the arms of said Wheatstone bridge arrangement, a rheostat, and means for connecting said rheostat in series with either of said arms of the Wheatstone bridge arrangement.

3. Apparatus for determining the location of a fault in one of the conductors of a cable comprising a Wheatstone bridge ar-

5 rangement, the faulty conductor being grounded at its distant end and being connected as one of the arms of the Wheatstone bridge arrangement, a good conductor connected as another of the arms of said Wheatstone bridge arrangement, a rheostat, means for connecting said rheostat in series with either of said arms of the Wheatstone bridge arrangement, means for applying an alternating potential to one of the diagonals of the Wheatstone bridge arrangement, means for changing the phase of said alternating potential by 90 degrees, means for converting any alternating potential received from the other diagonal of the Wheatstone bridge arrangement into a steady direct current, and a galvanometer upon which the steady direct current is impressed.

20 4. Apparatus for locating a fault in a cable conductor while preventing the effect of induced potentials from interfering with the apparatus comprising a good conductor of the same cable, a condenser connected in series with the good conductor, the faulty conductor being grounded at the distant end, and a Wheatstone bridge arrangement for comparing the capacitance to ground of the faulty conductor with that of the good conductor and condenser.

30 5. Apparatus for determining the location of a fault in a cable conductor while maintaining the apparatus substantially free from interference caused by induced currents, comprising a good conductor located in the same cable, a condenser connected in series with the good conductor, a Wheatstone bridge arrangement for comparing the capacitance to ground of the faulty conductor with that of the condenser and good conductor, a rheostat, and means for connecting said rheostat in series with either of said conductors.

40 In testimony whereof, I have signed my name to this specification this 29th day of December, 1931.

45 PAUL G. EDWARDS.