June 25, 1935. L. BEHR 2,005,986

IMPEDANCE SET

Filed Dec. 4, 1931 2 Sheets-Sheet 1

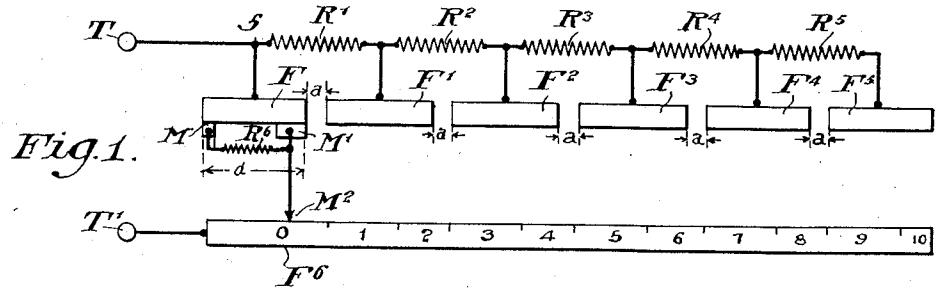


Fig. 1.

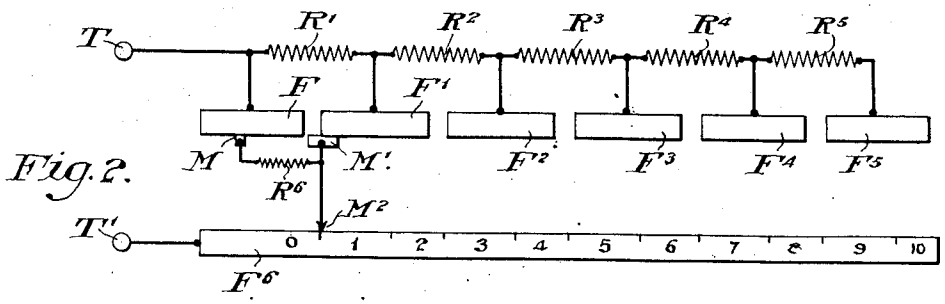


Fig. 2.

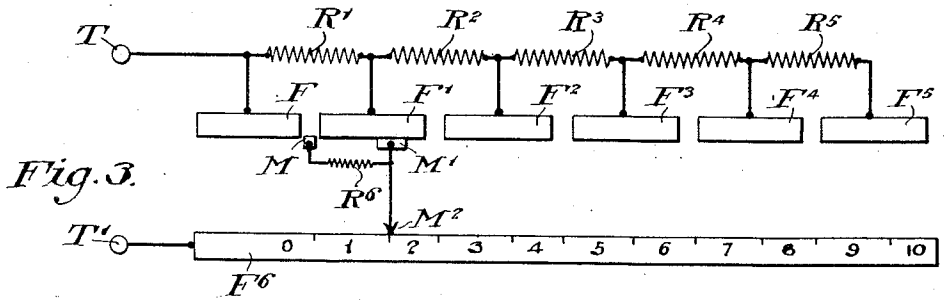


Fig. 3.

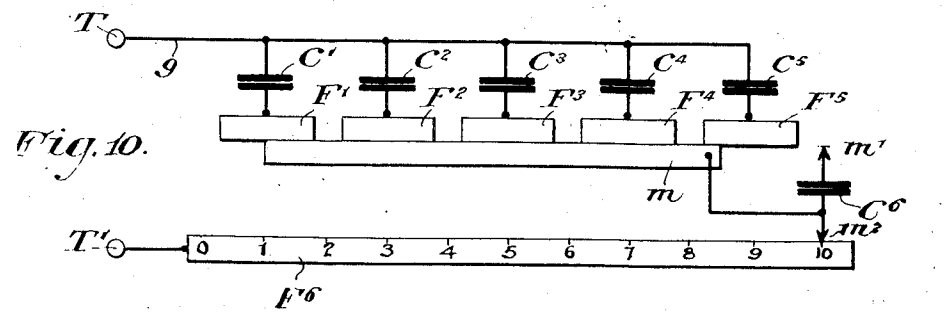


Fig. 10.

Inventor
Leo Behr
By Cornelius L. Eltz
his Attorney

June 25, 1935. L. BEHR 2,005,986

IMPEDANCE SET

Filed Dec. 4, 1931 2 Sheets-Sheet 2

Fig. 4.

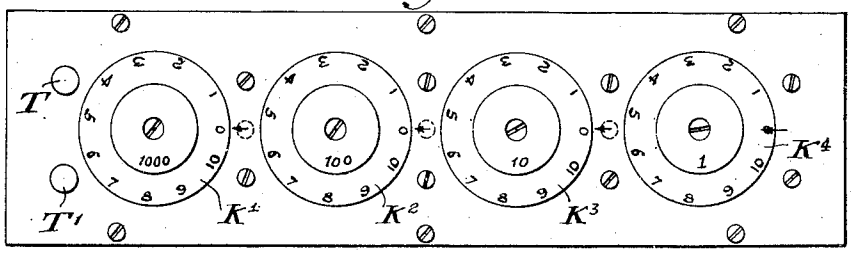


Fig. 5.

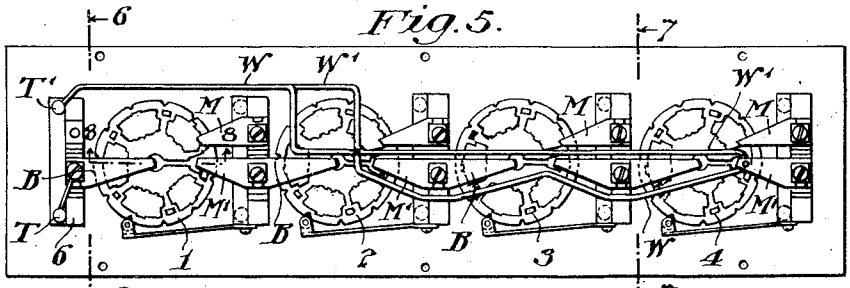


Fig. 9.

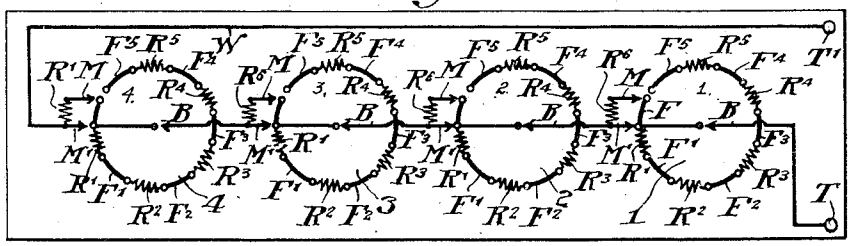


Fig. 6.

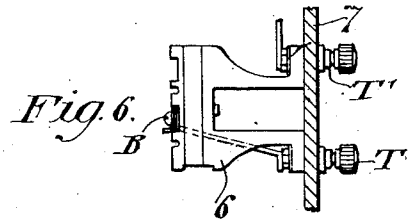


Fig. 7.

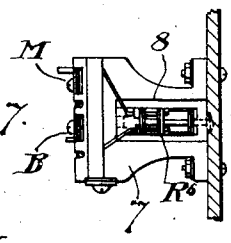
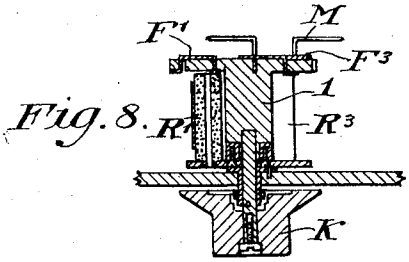


Fig. 8.



Inventor
Leo Behr
By Cornelius L. E. Bret
His Attorney.

UNITED STATES PATENT OFFICE

2,005,986

IMPEDANCE SET

Leo Behr, Philadelphia, Pa., assignor to Leeds & Northrup Company, Philadelphia, Pa., a corporation of Pennsylvania

Application December 4, 1931, Serial No. 578,951

8 Claims. (Cl. 201—48)

My invention relates to reactance or resistance sets, such as decade sets, for introducing known values of reactance or resistance into an electrical system, particularly a measuring circuit or network.

In accordance with my invention, the number of resistors or reactors is not only less than the number of possible steps but the arrangement is such that the transition from one setting to the other does not introduce values of resistance or reactance which are outside of the initial and final settings.

More specifically equal reactances are connected so that for the maximum setting, their values are additive, i. e., resistances, or inductances, are connected in series, while condensers are connected in parallel, and alternate lesser steps are obtained by progressively excluding the resistances or reactances from circuit. The intermediate values between the alternate steps are obtained by including in circuit with the last active resistor or reactor, an auxiliary resistor or reactor, of such value and in such circuit relation that the effective value of the last active resistor or reactor is halved.

My invention further resides in the features of combination and arrangement hereinafter described and claimed.

For an understanding of my invention and for illustration of some of the forms it may take, reference is to be had to the accompanying drawings in which:

Figs. 1 to 3 diagrammatically illustrate a resistance box for different settings to obtain different resistance values.

Figs. 4 and 5 are top and bottom plan views respectively of a resistance box.

Figs. 6, 7 and 8 are detailed views taken respectively on lines 6—6, 7—7, and 8—8 of Fig. 5.

Fig. 9 is a wiring diagram of the resistance box of Figs. 4 and 5.

Fig. 10 diagrammatically illustrates a reactance or condenser box.

Heretofore, in resistance sets in which the number of resistances was less than the number of steps or settings, it was necessary in changing from one setting to the next, either to open a circuit, in which event the effective resistance of the box became temporarily infinite, or one or more resistance sections were short-circuited, so that the value of effective resistance of the box to the external circuit was lower than both settings. More generally expressed, with the previously known arrangements, in the transition from one setting to the next, there was temporarily introduced into the external circuit a resistance value which lay outside the initial and final settings.

Referring to Fig. 1, the resistance sections or units R1, R2, etc., are connected in series with each other to one terminal T of the set. The resistors are preferably equal in value, and the value of each resistance is double that of the increment of resistance effected in changing from one setting of the box to the other. The resistances are connected to a series of contacts F, F1, etc. The contacts M and M1 whose relative position remains fixed, are adapted successively to engage the series of contacts F to F5, for different settings. The contacts M, M1 may be moved, preferably together as a unit, or they may remain fixed, and the contacts F, F1, etc., moved successively into engagement with them.

For simplicity, contacts F to F5 are shown of equal length and equally spaced. Contact M1 is suitably greater in length than the distance "a" between the adjacent ends of contacts F, F1, etc. Contact M is suitably shorter than the distance "a" between the same contacts. The distance between the remote edges of contacts M and M1 should be less than the distance between the centers of any pair of adjacent contacts F, F1, etc.

Particularly for convenience of explanation, the contact plate F6 is shown provided with a scale corresponding numerically to the resistance settings. For the position of contacts shown in Fig. 1, the resistance setting is zero, the current entering the terminal T, for example, passing directly to contact F without traversing any of the resistance sections, and then through contact M1 to the other terminal T1 of the box.

In going to the next higher setting, Fig. 2, the contact M1 first engages contact F1 and upon further movement and while still in engagement with contact F1, passes out of engagement with contact F, connecting resistance R6 in shunt to resistance R1. Preferably the resistances R6 and R1 are of equal magnitude so that the effective resistance across the terminals T, T1, is half the value of either of the resistances. In this transition from the zero setting to the next higher, the resistance introduced in the external circuit did not exceed the final setting for until resistance R6 was connected in shunt to resistance R1, it was short circuited by the contact F and as soon as this short circuit was removed by the contact M1 passing beyond contact F, resistance R6 was immediately connected

in shunt to resistance R1, so that at no time was the circuit interrupted, or either R1 or R6 alone in circuit.

To increase the setting still further, the contacts M, M1, are again moved to the right, the resistance in the external circuit remaining at the lower value until the trailing edge of contact M passes off contact F (Fig. 3) whereupon all of the current at once flows through resistance R1 only. Again in the transition, the circuit between terminal T, T1 is maintained closed and the resistance changed directly from one value to the next.

For the next higher setting, the contacts M, M1 are further moved to the right to the next zone of the scale. During this movement, the contact M engages contact F1, without effecting any resistance change, since the resistance R6 is short circuited by the engagement of F1 with both of the contacts M, M1. As soon, however, as the contact M1 passes beyond the contact F1, the current, all of which flows through resistance R1, divides, part going through resistance R2 and the remainder through resistance R6. The effective resistance in circuit is therefore now the sum of resistance R1 plus half the resistance of either resistance R2 or R6. The change in setting did not introduce temporarily any value of resistance outside of the third and fourth setting (scale readings 2 and 3) for the resistance R1 remained in circuit until contact M1 left contact F1, and then R6 was immediately connected in shunt to R6 without any circuit interruption, and without effecting any other temporary circuit connection of any of the resistors.

From the foregoing, it is to be understood that for alternate settings, one of the resistance sections R1, R2, etc., is included or excluded from circuit, while for the intermediate, or every other setting, the resistance R6 is in shunt to the last active section. It is apparent from the foregoing that with this arrangement of contacts and resistances the transition from one setting to the next does not introduce any resistance value which lies outside the final or initial settings.

For a decade set, that is, one having ten steps, of equal value, only six resistors are required, and these as above stated, for equal increments of resistance, are all of an equal value which is twice the increment change. For example, if the set is for varying the resistance from zero to 100 ohms in 10 ohm steps, each of the resistances R1 to R6 will have a value of 20 ohms.

It is further to be noted that in my arrangement the circuit connections and contact arrangement is simple, which permits reliable operation and affords ease of construction.

In Figs. 4 to 9 there is shown a resistance box utilizing in series of four arrangements such as have been described, so that the box may be set to obtain widely varying resistance values, in both large and small steps. Upon each of the rotatable drums 1 to 4, are mounted a group of resistors connected in series, each group corresponding to the resistances R1 to R5 of Fig. 1, the resistors of the several groups having different values. The resistors are preferably of the woven type and mounted on cylindrical forms as more clearly shown and claimed in copending Tarpley application Serial No. 586,518, filed January 14, 1932, which has since issued as Patent 1,992,499, Sept. 4, 1934. The contacts F1 to F5, connected to the resistances, are carried by the drum and successively engage the fixed contacts M, M1, as the drum is rotated by a knob which can be manipulated from the exterior of the housing or box to change the resistance settings.

A brush B engages the terminal contact 5 at the center of each drum which is connected to contact F and corresponding end of resistance R1. The bracket or support 6 for holding the brush B, is held to the top panel 7 by the binding posts or terminals T, T1, as most clearly shown in Fig. 6. Each of the remaining brackets 7, each of which carries a pair of contacts M, M1, is provided with a recess or opening 8 in which a resistance R6 is disposed. The connections to the several contacts M, M1 and brushes B are most clearly shown in Fig. 9.

The mounting of the main resistors upon the drums is of material advantage as it not only reduces the cost of construction, but increases the dependability by greatly reducing the number of sliding contacts and the number of joints in the electrical path between the groups of resistors. With the construction shown, the conductors and brushes carrying current to the resistors remain in the same position.

By way of example only, the dial K1 (Fig. 4) may be for adjusting the resistance from zero to 10,000 ohms in steps of 1000 ohms, in which case the resistances R1 to R6 of the first section of the box would each have a value of 2000 ohms; the dial K2 is for adjusting the resistance of the second section from zero to 1000 ohms in 100 ohm steps, and the resistances R1 to R6 of that section will each have a value of 200 ohms; similarly the knob K3 may be for adjusting the resistance of the third section from zero to 100 ohms in 10 ohm steps, in which case the resistance R1 to R6 will each have a value of 20 ohms; and the dial K4 may be for adjusting the resistance from zero to 10 ohms in 1 ohm steps, in which case each of the resistances R1 to R6 will have a value of two ohms. In this box, using only 24 resistances, the resistance introduced into the external circuit may be varied from zero to 11,110, by 1 ohm steps if desired, and throughout this range a transition in any one dial from one setting to the next does not introduce into the external circuit any resistance value which is outside of the initial and final setting, and more specifically for a change in setting the resistance changes directly from one value to another. Notches in the bottom flanges of the drums engage a spring-pawl or equivalent "click" device to ensure proper relation of contacts M and M1 with respect to contacts F to F5 for the eleven positions of each drum.

It is also a characteristic of the arrangement shown that the inductive and capacity effects are minimized. For example, the connection from terminal T1 of the box to the brush M of the lowest resistance group on drum 4 is made by wires W and W1, connected in parallel. These wires, as shown in Fig. 5, pass on opposite sides of the two brushes B, M1 between drums 2, 3 and 4, and as the current flow through them is in a direction opposite to the current flow through the brushes, the inductive effects are substantially annulled. To minimize capacity effects, the conductors W, W1 are substantially spaced from the resistors of drum 1 and associated conductors, which are of materially different potential.

While I have described my invention as specifically applied to resistance boxes, the same principles may be utilized for reactance boxes, that is, in which inductance or capacity is changed by incremental steps. The connections

and switching arrangement for inductances are the same as for resistance. Precaution should be taken to avoid coupling between the inductances, i. e. the inductances should be so positioned or so shielded that there is zero or insubstantial interlinkage of their fields.

Since capacities are additive when connected in shunt instead of being additive when connected in series, as is the case with inductances and resistances, a modification of the connections and contact arrangement is made. Fig. 10 illustrates a decade set, affording 10 equal steps of capacity by using only six condensers, and is characterized by the fact that in changing from one setting to another there is not introduced into the external circuit any capacity which is beyond the initial and final settings.

The condensers C1, C2, etc., each have one terminal connected to a conductor 9 extending to terminal post T. The other terminals of the condensers are connected respectively to contacts F1 to F5. At the setting for maximum capacity, all of these contacts are engaged by the contact *m*, so that the condensers C1 to C5 are all connected in parallel across the binding posts T, T1. For the next lower setting, the contact *m* engages only contacts F1 to F4, and the contact *m1* engages contact F5 to connect the condenser C6 in series with condenser C5. As the condensers C1 to C6 are of equal value, the effective capacity of C5 in series with C6 is only half the value of either. The total capacity for this setting is therefore equal to the sum of the capacities of condensers C1 to C4 plus half the capacity of condenser C5. For the next lower setting, the contact *m* continues to engage contacts F1 to F4, but the contact *m1* moves to a position intermediate contacts F4 and F5, so that there is included in circuit only the condensers C1 to C4.

Accordingly, as the contacts *m*, *m1* move to the left, the condensers C4 to C1 are successively excluded from circuit for each second movement of the contacts, while for every other movement or intermediate setting, the condenser C6 is inserted in series with the last active condenser to halve its effective magnitude. If it is desired to change capacity from zero to 10 mfds., for example, in steps of 1 mfd., each of the condensers C1 to C6 should have a value of two mfds.

For extending the range of capacity change which can be effected in the circuit connected to terminals T, T1, several arrangements such as shown in Fig. 10 may be connected in parallel, and preferably the values of capacity of the units of the several sets will bear a decimal relation to each other.

For convenience, the term "set" appearing in the claims means a group of impedances under the control of a common switching system, and the term "box" applies to two or more "sets" with connections.

What I claim is:

1. A resistance box comprising at least two units each comprising a rotatable structure, a plurality of resistors carried by said structure, a series of angularly spaced contacts mounted on said structure and connected to said resistors, and a terminal contact mounted on said structure; a stationary contact brush in continuous engagement with the terminal contact of one of said units, a stationary contact brush for successively engaging the angularly spaced contacts of another of said units, and a stationary contact brush for engaging the terminal contact of one unit and for successively engaging the angularly spaced contacts of an adjacent unit.

2. A resistance box comprising at least two units each comprising rotatable structure, a plurality of resistors carried by said structure, a series of angularly spaced contacts mounted on said structure and connected to said resistances, and a terminal contact mounted on said structure; a stationary contact brush for engaging the terminal contact of one unit and for successively engaging the angularly spaced contacts of an adjacent unit, a second contact brush for successively engaging the angularly spaced contacts of said adjacent unit, and a stationary auxiliary resistor connected between said contact brushes.

3. A resistance box comprising at least two units each comprising rotatable structure, a plurality of resistors carried by said structure, a series of angularly spaced contacts mounted on said structure and connected to said resistances, and a terminal contact mounted on said structure; terminal posts for said box, contact brushes for connecting said units in series, and means for minimizing inductive effects comprising conductors from one of said brushes to one of said binding posts, said conductors being disposed on opposite sides of at least one other of said brushes in which the current flow is opposite in direction to the current flow through said conductors.

4. A resistance box comprising at least two rotatable drums having parallel axes of rotation, a plurality of resistances of fixed and equal magnitude mounted on each of said drums and angularly spaced about the axis thereof, a plurality of angularly spaced contacts mounted at one end of each of said drums and connected to said resistances, a terminal contact mounted on said one end of each of said drums, and a contact brush for continuously engaging the terminal contact of one drum and for successively engaging the angularly spaced contacts of an adjacent drum.

5. A resistance box comprising at least two units each comprising a rotatable structure, a plurality of resistors of fixed magnitude carried by said structure, contacts mounted on said structure and connected to said resistors thereon, and a stationary brush connecting a predetermined contact of one of said rotatable structures selectively to any of the contacts of another rotatable structure.

6. A resistance box comprising a rotatable drum, a plurality of equal and serially-connected resistances carried thereby and rotatable therewith, angularly-spaced contacts carried by said drum and connected to said resistances, a pair of stationary contacts adapted to engage adjacent of said angularly spaced contacts for alternate settings of said drum and to engage the same contact for intermediate settings of said drum, and a stationary resistance equal in magnitude to each of the rotatable resistances continuously connected between said stationary contacts.

7. A resistance box comprising a rotatable drum, a plurality of equal and serially-connected resistances carried thereby, angularly spaced contacts carried by said drum, a pair of stationary contacts for cooperating therewith, a stationary resistance equal in magnitude to each of said rotatable resistances connected between said stationary contacts, an index and scale coupled to said drum, and means for accurately arresting said drum upon relative movement of said index and scale in one direction alternately in positions for which said stationary contacts engage adjacent contacts carried by said drum and in intermediate positions for which said stationary con-

tacts engage one of said rotatable contacts whereby the resistance of the box is varied by steps each equal to one-half the magnitude of each of said resistances.

8. A resistance box comprising a movable indicating member indicating a number of resistance values differing progressively by equal increments for successive settings of said indicating member in one direction, a pair of contacts, a resistor continuously connected between said pair of contacts and of a magnitude twice the increment, a plurality of resistors connected in series and each of the same magnitude as said first resistor, a plurality of contacts connected to said plurality of resistors, and means operable upon movement of said indicating member to effect relative movement between said plurality of contacts and said pair of contacts, the dimensions and spacing of said contacts in the direction of movement being such and so related to movement of the indicating member that when said indicating member indicates even multiples of said increment said first resistor is effectively out of circuit and when said indicating member indicates odd multiples of said increment said first resistor is in shunt to one of said plurality of resistors effectively in circuit.

LEO BEHR.

CERTIFICATE OF CORRECTION.

Patent No. 2,005,986. June 25, 1935.

LEO BEHR.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 72, for the patent number "1,992,499" read 1,972,499; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of July, A. D. 1935.

Leslie Frazer

(Seal) Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 2,005,986. June 25, 1935.

LEO BEHR.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 72, for the patent number "1,992,499" read 1,972,499; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 16th day of July, A. D. 1935.

Leslie Frazer

(Seal) Acting Commissioner of Patents.