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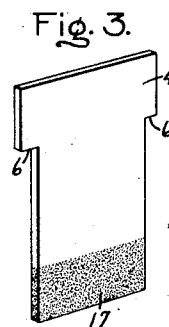
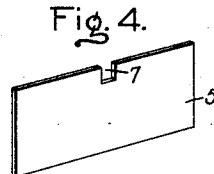
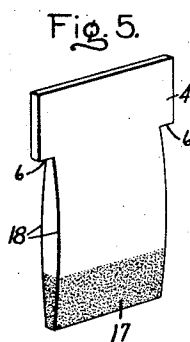
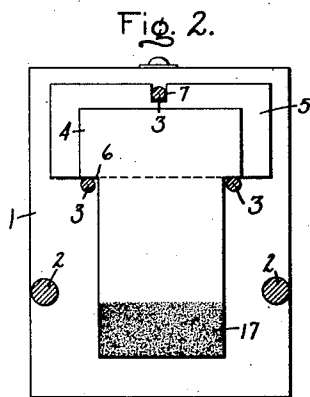
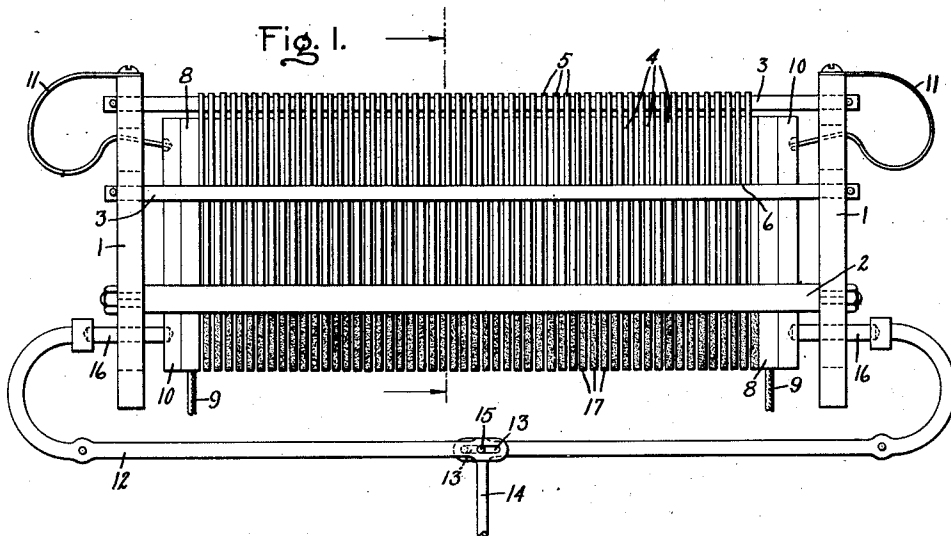
L. W. THOMPSON

2,136,257

VARIABLE RESISTANCE DEVICE

Filed June 4, 1937

5 Sheets-Sheet 1



Inventor:
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by *Harry E. Dunham*
His Attorney.

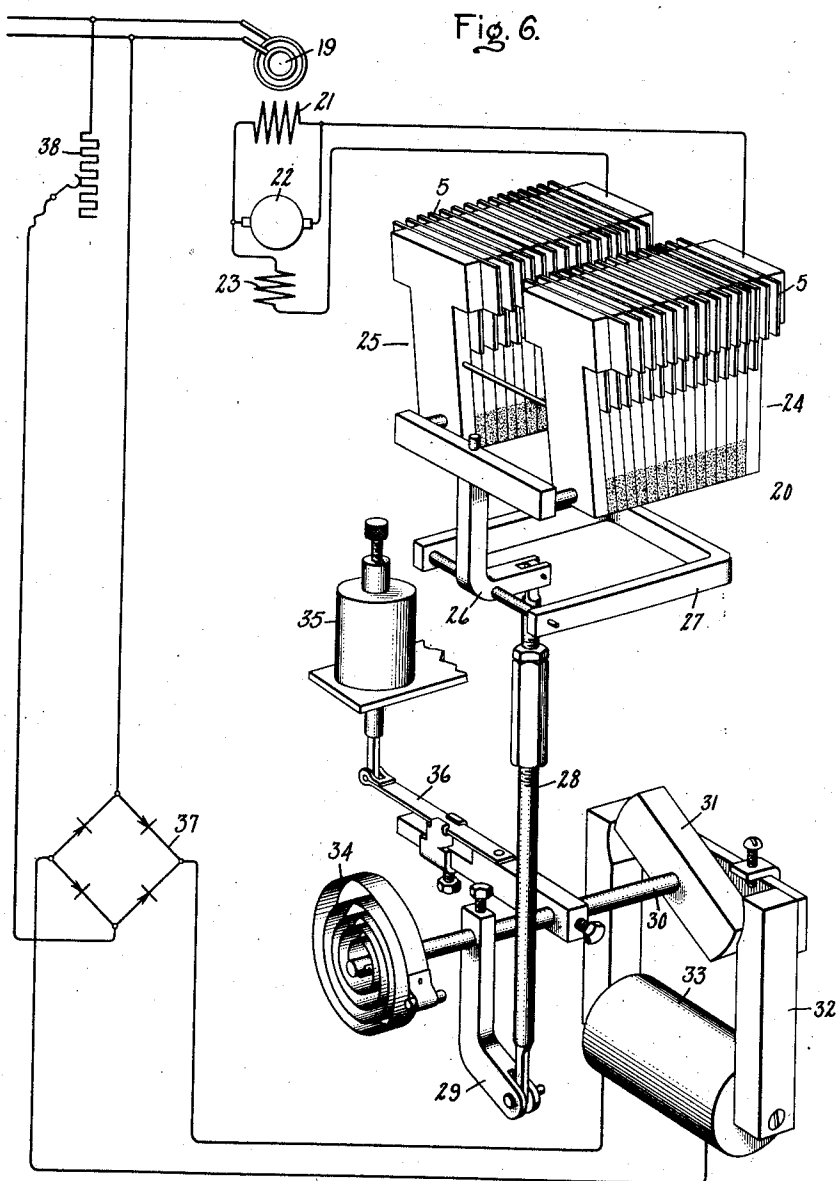
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VARIABLE RESISTANCE DEVICE

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5 Sheets-Sheet 2



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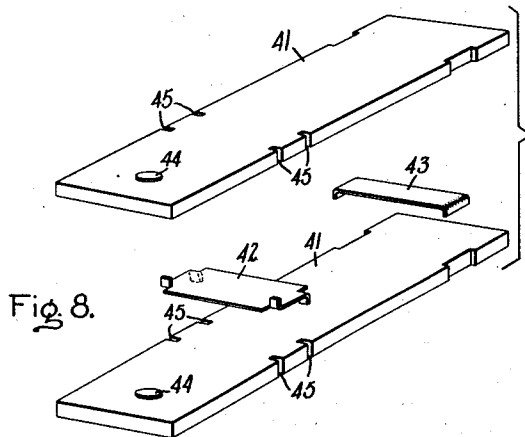
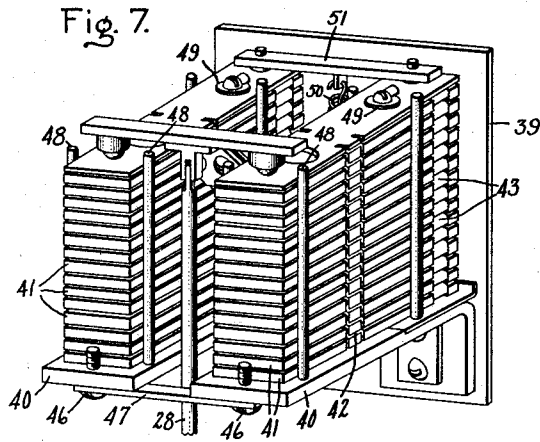
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2,136,257

VARIABLE RESISTANCE DEVICE

Filed June 4, 1937

5 Sheets-Sheet 3



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2,136,257

VARIABLE RESISTANCE DEVICE

Filed June 4, 1937

5 Sheets-Sheet 4

Fig. 9.

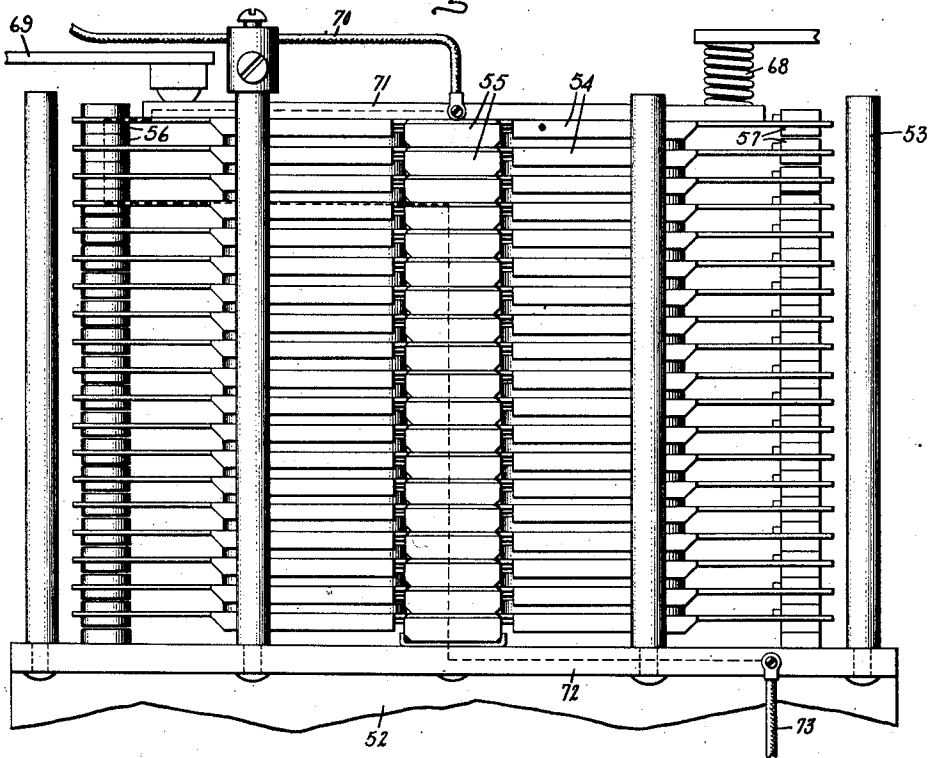
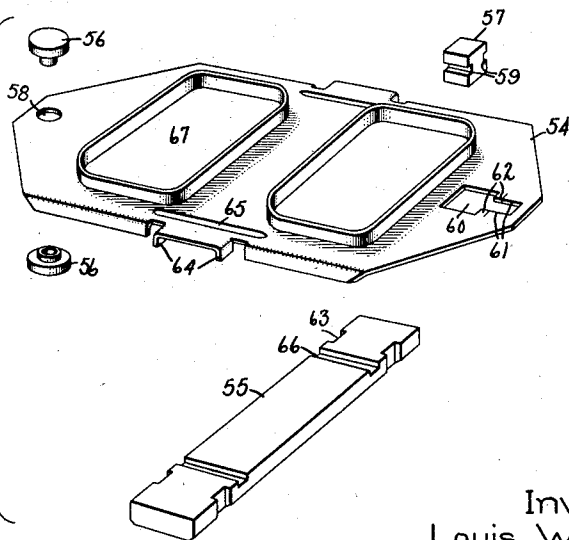


Fig. 10.



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UNITED STATES PATENT OFFICE

2,136,257

VARIABLE RESISTANCE DEVICE

Louis W. Thompson, Schenectady, N. Y., assignor
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New York

Application June 4, 1937, Serial No. 146,419

26 Claims. (Cl. 201—51)

My invention relates to variable electrical resistance devices and more particularly to improvements in pile type electrical resistance devices.

This is the last of a series of three continuations-in-part of my original application Serial No. 699,722 for Variable resistance devices, filed November 25, 1933, and assigned to the assignee of the present application. The other two were Serial No. 743,849, filed September 13, 1934 and Serial No. 52,543, filed December 2, 1935.

Pile type resistances or rheostats, of which the best known example is the well known carbon pile, usually operate in such a manner that as the pressure on the pile is increased the electrical resistance is decreased. An explanation of this is that the increasing pressure increases the area of contact between the microscopically rough carbon surfaces thus reducing the contact resistance. The resistance range of an ordinary carbon pile is rather limited because even with full pressure applied to the pile, the minimum resistance is still appreciable, while when no pressure is applied to the pile it is very sensitive to vibration and arcing occurs between the carbon elements or plates, thereby causing the maximum resistance of the pile to be unstable. Consequently, for best operation some pressure must always be applied to the pile, with the result that maximum resistance of the pile is decidedly limited.

In my Patent No. 2,026,405 for Variable electrical resistance device, granted December 31, 1935 and assigned to the assignee of the present application, I have disclosed and claimed an arrangement for reducing the minimum resistance of a pile resistance or rheostat to practically zero. This is done by permanently short-circuiting corresponding sections of the elements or plates of the pile and arranging the elements in such a way that the short circuited portions are in engagement when full pressure is applied to the pile. As a result, the pile is substantially short circuited and the resistance is substantially zero.

The resistance of a pile type rheostat, such for example as a carbon pile resistance, consists largely of the surface contact resistance between the discs, plates or wafers comprising the pile. It has been proposed in the past to interpose or interleave metal elements between the carbon elements as this has been found to increase the specific surface contact resistance of the device. A possible explanation of this phenomenon is that as the contact surfaces of adjacent carbon elements are substantially equally microscopically rough, their minute projections and indentations tend to fit into each other, thereby increasing the area of contact and reducing the specific contact resistance, whereas when the contact is

from carbon-to-metal or from metal-to-carbon, the metal being smoother, only the high points of the carbon are in contact with the metal, thereby decreasing the contact area and increasing the specific contact resistance. By specific contact resistance is meant the resistance per unit area of contact.

It is preferable from the standpoint of reliability and uniformity of the characteristics of a pile resistor to use a corrosion-resistant or non-oxidizable metal or alloy, such for example as rustless steel or chromium nickel-iron alloys, examples of which are known to the trade as "Ascaloy" and "Nichrome".

In accordance with my invention, I provide a pile type variable resistance which comprises a novel combination of the features of my above referred to application and of the previously proposed idea for increasing the contact surface resistance of such devices. In other words, I provide a device which has a high resistance electrical conducting path comprising alternate surface contact resistances between any suitable different materials, and these alternate surface contact resistances are capable of being successively short circuited when pressure is applied to the device, so as to produce a substantially smooth and continuous decrease in resistance. With such an arrangement, it is possible easily to obtain a pile resistance having a resistance range of 500 to 1. Furthermore, the successive short-circuiting action can be obtained by successively rocking one set of alternate elements on the other set. This requires but a relatively small force so that my device is not really a "compressible" pile in the sense that an ordinary carbon pile is compressed by application of a relatively large force. By successive short circuiting of the contact resistances I mean the short circuiting of these contact resistances cumulatively, one at a time, regardless of the order of progression of the short circuiting action. For example, if the contact resistances are numbered 1, 2, 3, 4, etc., the short circuiting action may be in the order 1, 2, 3, 4, or 3, 2, 4, 1, or 4, 3, 2, 1, etc.

In accordance with a further feature of my invention, I provide a novel pile type resistance structure which is simple and inexpensive to construct and assemble and whose resistance is relatively stable in any part of its resistance range. It is also relatively independent of vibration.

An object of my invention is provide an improved variable electrical resistance device.

Another object of my invention is to provide a pile type resistance having an improved operating characteristic.

Another object of my invention is to provide a pile type resistance having an unusually wide resistance range.

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My invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

5 In the drawings, in which similar reference characters refer to similar elements throughout the several views, Fig. 1 is an elevation of a pile type rheostat embodying one species of my invention; Fig. 2 is a cross section of Fig. 1; Fig. 3
10 is a detail view of a resistance element of the rheostat of Figs. 1 and 2; Fig. 4 is a detailed view of a metal insert for use between the resistance elements in the rheostat of Figs. 1 and 2; Fig. 5 shows a modified form of carbon plate; Fig. 6 is a diagrammatic and skeletonized view
15 of an automatic generator voltage regulating system containing a regulator employing another species of my pile type resistance; Fig. 7 illustrates a further modification of my invention; Fig. 8 is a detailed view of the units making up the resistance shown in Fig. 7; Fig. 9 illustrates
20 a further modification in which large metal and small carbon elements are used; Fig. 10 is an exploded detail view of the elements used in Fig. 9; and Fig. 11 is a modified combination of Figs. 6 and 7 for giving stable operation when the whole device is tilted.

Turning now to Figs. 1 and 2 of the drawings, the rheostat comprises end plates 1 of suitable
30 insulating material, such for example as Bakelite, which are spaced apart by rods 2 bolted at each end to the plates 1. Running between the end plates 1 are three insulated rods 3 which pass through holes in the end plates 1 and which
35 serve to support the elements of the pile resistance. The resistance comprises alternate layers, elements or plates of carbon or graphite 4 and metal 5. As shown more in detail in Fig. 3, the carbon plates 4 are so constructed that they have over-hanging portions 6 which coast with
40 the two lower rods 3 and are supported thereby. As shown in Fig. 4 the metal plates 5 are flat and are provided with an upper notch 7 through which the upper rod 3 passes for maintaining these elements in place. At each end of the
45 pile are terminal blocks 8 of suitable conducting material to which leads 9 are fastened in any suitable manner. Outside the terminal blocks 8 are plates 10 to which pressure is applied at each end by any suitable means, such as by springs
50 11 which are fastened to the top of the end members 1.

Means, shown as pivotally mounted levers 12, are employed for applying a variable pressure to the pile resistance. As shown, the levers 12 have
55 slots 13 which are engaged by a rod 14 through which a pin 15 is passed, and the other ends of the levers 12 are connected to the ends of the pile by pins 16 passing through suitable holes in the end members 1. With this arrangement,
60 as the rod 14 is moved downwardly, the levers 12 pivot, thereby forcing the pins 16 inwardly and applying pressure to the pile.

The lower end of the carbon plates 4 are shown
65 short circuited by any suitable means, such as by silver plating 17 thereon. This feature, however, in and of itself, forms no part of my present invention and is described and claimed in my above referred to patent.

70 The operation of Fig. 1 is as follows: With the parts in the position shown in the drawings, minimum pressure is applied to the pile and due to the spacing of the carbon plates by the intermediate metal plates 5 the conducting path
75 through the pile is through the upper portion

thereof and any current will have to flow through the contact resistances between the metal plates and the carbon plates. I have found that this produces a relatively very high resistance, even when sufficient pressure is applied by the springs 11 to hold the elements relatively firmly in position so that moderate vibration will not affect the resistance of the pile. If now it is desired to decrease the resistance of the pile, the lever 14 is moved downwardly by any suitable means (not shown) with the result that the lower ends of the pile successively come into engagement. This results in a gradual decrease in the resistance of the conducting path through the pile until finally all of the lower or plated ends of the carbon elements 5 are in engagement with the result that the pile is substantially short circuited and its resistance will be a minimum. During intermediate stages only the plated ends of the outer plates of the pile will be in engagement and the conducting path will be through the short circuited ends of the outer plates and then between the upper ends of the intermediate plates. As pressure is progressively applied, more and more of the lower ends come in contact so that the conducting path tends more and more to be through the lower or short circuited ends of the carbon elements.

When the conducting path is through the alternate carbon and metal elements, I have found
3 that the characteristic of the arrangement is such that it has an instantaneous non-linear characteristic with changes in current. Thus, I have found that increases in current through the pile, such for example as may be caused by increases
3 in circuit voltage, cause a reduction in the electrical resistance of the pile and vice versa. This change in resistance is entirely independent of changes in temperature. This characteristic is often useful in electrical circuits where negative
4 resistance-current characteristic resistances are needed. It is especially valuable in a rheostat used as a regulating resistance, such as in series with a field winding of a dynamo-electric machine, for then the negative characteristic automatically increases the range of control. Thus
4 the decrease in current caused by a controlled increase in resistance in turn causes an inherent further increase in resistance due to the negative resistance-current characteristic and vice versa.
5 Therefore a given controlled resistance range is supplemented by an inherent automatic current responsive resistance range and the overall range of control is substantially extended.

Another advantage of the negative impedance current characteristic of the contact resistances is that it inherently limits the voltage between the low contact resistance portions or metal contacts of the elements which short circuit the relatively high negative characteristic contact
6 resistances. This is because as the current increases the impedance or resistance decreases so that the voltage drop in the negative resistances does not increase at the same rate as the current does or as the voltage drop would increase in an ordinary linear resistance. This, therefore, reduces contact sparking and pitting and radio interference as a result of operation of the device.

Although the arrangement of Fig. 1 operates in a satisfactory manner, I have found that sometimes its action can be improved if the middle portion of the carbon elements 4 are slightly thickened, or bulged, as is shown (exaggerated) at 18 of Fig. 5. This thickening is insufficient to cause contact between the carbon elements when

they are in the minimum pressure position, but as pressure is applied, the upper ends of the elements of the carbon pile tend to separate and the thickened middle portions of the carbon elements come into engagement before the lower or short circuited ends come into engagement. This results in a smoother change of resistance with changes in pressure on the pile because there is an intermediate carbon-to-carbon contact stage having an intermediate resistance value.

Although the metal plates 5 have been shown smaller than the carbon plates 4 it is obvious that the relative size of these elements plays no part in the invention and that the metal plates 5 can be extended so that they are either equal to or greater in size than the carbon plates 4. All that is necessary is that the low contact resistance portions of alternate elements which are to form the short circuiting connections around the relatively high contact resistances be carried in such a way that they are normally out of contact with the intermediate elements.

In the regulating system shown in Fig. 6, there is illustrated by way of example, an alternating current generator 19 whose voltage it is desired to regulate by means of an automatic regulator 20. Generator 19 has a field winding 21 which is energized by an exciter 22 having a shunt field winding 23 in series with which is a pair of series connected variable resistance piles 24 and 25. These piles are in general similar to the pile of Figs. 1 and 2, the only real difference being that the metal spacers, or plates 5, instead of being provided with notches in their upper sides, are provided with side ledges similar to the carbon plates, so that both the metal plates and the carbon plates may be supported in the same manner by means of rods, such as the rods 3 shown in Fig. 1. For controlling the pressure on the resistance piles 24 and 25 there is shown a pivotally mounted means 26, supported by a suitable fixed frame 27, which is actuated by a rod 28. Rod 28 is connected by means of a crank member 29 to a shaft 30 fastened to an armature 31 of an electromagnet having a core 32 which is energized by an operating winding 33. Opposing the pull of the magnet is a coil spring 34 which is fastened to the other end of the shaft 30. For preventing hunting of the regulator and damping vibration thereof, there is provided a dashpot 35 which is connected to the shaft 30 through a blade spring 36. The coil 33 is connected to be responsive to the voltage of generator 19 by means of suitable circuit connections including a full wave rectifier 37, the purpose of which is to insure that the winding 33 is energized by direct current so that its energization will be independent of frequency changes of the generator 19. This is usually desirable in order that the pull of the electromagnetic assembly may be responsive to voltage and voltage only. In the energizing circuit for magnet 33 there is inserted a suitable control means such as a rheostat 38 for adjusting the voltage held by the regulator.

The operation of the arrangement of Fig. 6 is such that if the voltage of generator 19 departs from a predetermined normal value in either direction, the balance of forces in the electromagnetic assembly changes in such a manner that shaft 30 will turn, thereby causing a change in the pressure on the piles 24 and 25, whereby their resistances change in a manner to cause a corrective change in the current in the field winding of exciter 22. This changes the voltage of exciter 22, thereby changing the voltage of the

generator 19 and the arrangement is such that the change in voltage is made to correct for the change which has already taken place. For example, if the voltage of generator 19 should fall, the energization of magnet 33 is decreased, thereby decreasing the pull of this magnet on the armature 31 whereby the normal balance between this pull and the torque of spring 34 is upset and the spring 34 tends to unwind slightly, thereby moving the shaft 30 clockwise which causes the rod 29 to move downwardly, whereby the pivoted member 26 increases the pressure on the piles 24 and 25. This decreases their resistance, thereby increasing the excitation current for the exciter 22 whereby its voltage is increased. This in turn increases the current through the field winding 21 thereby increasing the voltage of generator 19. The electromagnetic assembly and the spring are constructed in a well known manner so that the shaft 30 will come to rest in any one of a reasonable range of angular positions thereof provided the voltage of generator 19 is at a predetermined normal value.

The modification shown in Figs. 7 and 8 is similar to that shown in Fig. 6 in that it is divided into two piles or stacks so as to get the required resistance value without taking up too much space. It is different from Fig. 6 and also from Fig. 1 in that the units are stacked vertically instead of horizontally. This has a certain advantage in cases where the supporting structure is subject to relatively wide angular movement, such for example as on shipboard. With the units shown in Figs. 1 and 6, the movement of a ship in a rough sea is often enough to cause accidental engagement of the low resistance or plated ends of the carbon elements at times when it is not desirable. However, by means of the vertical stacking shown in Fig. 7, the resistance of the device is substantially independent of vibration or reasonably limited angular movement of the supporting means.

The device shown in Fig. 7 may either be used as a manually operated rheostat or it may form the variable resistance part of a regulator, such as shown in Fig. 6, and if so used the rod 28 of Fig. 6 may be considered as the actuating member for the device of Fig. 7.

The device shown in Fig. 7 comprises a main supporting structure 39, carrying outwardly extending or normally horizontal brackets 40, on which are mounted the vertical variable resistance stacks comprising carbon plates or elements 41, between which are interposed or interleaved metal inserts 42, shown more clearly in Fig. 8. In addition, there are interposed between the plates 41 relatively poor electrical conducting inserts 43 which are also shown more clearly in Fig. 8 and which may comprise any suitable insulating material, or oxide or enamel coated metal. The means for securing substantially zero resistance of the pile comprises separate relatively good electrical conducting members which pass through each of the carbon plates at their outer ends (as viewed in Fig. 7). They may be in the form of flat headed silver rivets 44 passing through the plates as shown more clearly in Fig. 8.

It will be seen from Fig. 8 that the plates 41 are provided with irregularities in their outlines, shown as notches 45, and that the metal inserts are provided with upwardly and downwardly extending projections for engagement with these notches. By this construction, the stack or pile is locked together so that the plates and elements

cannot slide relatively to each other. Furthermore, it will be seen that these notches are placed nearest the ends of the plates having the silver inserts 44. Furthermore, the size of the inserts 42 is relatively small in comparison with the size of the plates 41, so that although the inserts 42 serve to separate the plates 41 the latter may be rocked about the inserts as effective pivots and due to the fact that these effective pivots are nearer the outer ends of the stacks, that is to say, nearer the ends of the plates 41 which have the inserts 44, the greater weight of the plates will be to the right, or to the inward end of the stacks, so that when no pressure is applied to the stack the ends of the inserts 44 will normally be separated. Due to the presence of the substantially insulating members 43 carbon-to-carbon contact is prevented so that the electrical conduction path through the stacks is from the carbon units to the metal units and from the metal units to the carbon units, alternately. When, however, pressure is applied to the device, for example by exerting a downward force on the rod 28, the silver buttons 44 progressively engage each other, thereby short circuiting the carbon-to-metal and metal-to-carbon contact surface resistances whereby the resistance of the pile is progressively decreased until full pressure causes the engagement of all the silver buttons, whereby each pile is substantially short circuited. Each of the stacks is fastened to its individual support 40 by means of the lowermost element or plate 41, which may be screwed or bolted thereto or fastened thereto by any other suitable means. Screws 46 at the outer ends of the supports 41 serve also to prevent outward movement of the bottom element of each stack and serve also to fasten a bridging conductor 47 in place. This conductor serves to connect electrically the two stacks. The stacks are held in position by means of vertical insulating rods 48. Electrical connections are made to the stacks by means of terminal 49 fastened to the top element of each stack.

Although as previously explained, when no pressure is applied to the pile, the inward ends of the units thereof tend normally to be together and the outward ends to be separated, it is sometimes desirable to provide positive means for insuring this result, so that as shown in Fig. 7, there is provided a tension spring 50 which, by means of a suitable yoke member 51 applies normally a relatively light pressure to the inward ends of the stack.

In the previously described embodiments of my invention the metal elements have been relatively small and the carbon elements have been relatively large so that the carbon elements were rocked about the metal elements by the application of pressure to the device. This, however, is not essential to my invention and if desired the relative sizes of the elements may be reversed so that the metal elements are the larger ones and the carbon elements are the smaller ones. A modification of my invention embodying such construction is shown in Figs. 9 and 10.

In Fig. 9 the resistance stack is mounted on suitable supporting means 52 in which are fastened vertical insulated rods 53. These rods serve as guides for confining the variable resistance stack which consists of alternate relatively large metal plates or members 54 and relatively small carbon elements or members 55. In order to improve the electrical contact between the metal members 54 there is inserted in the left-hand end

of each of them a separate metallic conducting contact 56. Electrical contact between the right-hand ends of the metal members 54 is prevented by providing each of these members with a separate insulating element 57.

The details of construction of one particular form of the metal and carbon members 54 and 55 may be seen more clearly in Fig. 10. A convenient way of attaching the metal contact 56, which may be of any suitable material such for example as silver, to the plate 54 is by making the contact in two parts which telescope into each other through a hole 58 in the plate 54. This telescoping may consist of a tight pressed fit which securely holds the two portions of the contact 56 together so that no further means for this purpose is necessary. The insulating member 57 may be constructed with notches 59 so that when the member 57 is inserted in a suitably shaped hole 60 and then slid outward the notches 59 will engage the sides 61 of a suitably sized and shaped slot in the plate 54. Tabs 62 are then turned up at the beginning of the slot so as securely to hold the insulating member 57 in position.

Somewhat similarly to the arrangements shown in Figs. 7 and 8, the carbon elements are provided with notches 63 which are engaged by downwardly extending portions 64 of the metal members. Such interlocking construction serves to lock the unit or stack together and serves to hold the parts in proper alignment. This action is further aided by punched or pressed depressions 65 in the plate 54 the undersides of which engage properly shaped slots 66 in the carbon members 55.

The metal members 54 may also be provided with relatively large cutaway openings 67 for the purpose of permitting relatively free circulation of air and thus improve the cooling of the device. As the holes 67 are in substantial alignment a chimney effect is produced resulting in very good circulation of air whereby heat generated at the relatively high contact resistance surfaces between the metal and the carbon can be carried off by air rising through the passage formed by the aligned openings 67. Furthermore the large metal members 54 act as good heat radiators whereby a further cooling effect is produced. In this manner the heating effect of a relatively large I²R or wattage can be dissipated in a relatively small sized resistance unit.

In Fig. 9 a suitable spring 68 serves to hold the insulating members 57 normally in engagement under which condition all of the contacts 56 will be out of engagement. An actuating member 69 when moved downwardly causes sequential or successive engagement of the contacts 56 from the uppermost progressively to the lowermost, thereby successively short circuiting the contact resistances between the metal and carbon elements and at the same time causing separation of the insulating members 57. As shown in the drawings, some pressure is being applied by the member 69 because the four uppermost contacts 56 are in engagement while the three uppermost insulating members 57 are out of engagement. Under these conditions a current entering the device by a conductor 70 will flow to the left through a suitable conducting top plate 71 then through the four uppermost contacts 56, as shown by the dotted line representing the current flow, thence to the right along the fourth metal plate 54 and vertically downward through the alternate metal-to-carbon and carbon-to-metal contact resistance paths to a bottom conducting plate 72 and thence away from the stack through a suitable conduc-

tor 73. Varying the pressure produced by the member 69 varies the number of contacts 56 in engagement thereby varying the overall resistance of the stack.

In Fig. 11, the resistance stacks of Fig. 7 have been rearranged so as to adapt them for operation in places where the supporting means is subject to a rolling or rocking motion as on shipboard and these resistance stacks have been connected in a regulating circuit which in general is similar to the regulating circuit shown in Fig. 6.

I have found that when one of the resistance stacks of the type shown in Fig. 7 is tilted so that the end having the contact buttons 44 is lower than the end having the insulating strips 43, the resistance of the stacks tends to decrease whereas when the pile is tilted in the opposite direction so that the contact button ends of the elements are above the ends between which the insulating strips 43 are placed that the resistance increases. One explanation of this is that the tabs on the metal spacers 42 which engage the slots 45 as shown more clearly in Fig. 8 permit of some sliding motion of one plate on top of the other so that as the stack is tipped the center of gravity shifts causing the downwardly pointing ends of the elements to come together.

In Fig. 11 this effect is neutralized by reversely positioning the two stacks and as shown therein one stack has its contact button end outward and its insulated strip inward while the left-hand stack is reversely positioned and has its insulating members on the outer end and its contact button at the inner end. When such an arrangement is tilted, the resistance increase of one stack will be offset by the resistance decrease in the other stack so that when these resistance stacks are connected in series there is a negligible resistance change for the two stacks as a whole when the device is tilted.

In order further to insure stability of resistance with change in position each of the stacks is operated by its own rod 28 which is connected positively to the topmost plate of each stack by means of extension pieces 74 fastened rigidly thereto. Thus as the crank arm 29 rotates in the clockwise direction as viewed in the drawings, the right-hand stack has its resistance decreased in a positive manner while the left-hand stack also has its resistance decreased in a positive manner. Similarly when the cross arm 29 is turned in the opposite direction, both stacks have their resistance increased in the positive manner. The return spring present in Fig. 7 may therefore be dispensed with.

In order further to insure that the elements of the resistance stack stay in place, U-shaped yoke or saddle members 75 are placed over each stack and the lower end thereof or pivotally retained in uprights 76.

A conventional field rheostat 77 is connected in the exciter field circuit.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A variable resistance comprising a pile of electrical conducting elements of alternately different materials between which there is a rela-

tively high contact resistance, one set of non-adjacent elements being so arranged as to permit mutual short-circuiting engagement between portions of the other set of non-adjacent elements which are normally out of engagement, and means for causing successive engagement of said portions without changing substantially the pressure between said elements.

2. A variable resistance comprising a pile of alternate carbon and metal elements, the elements of one material being smaller than the elements of the other material and being aligned so that they will permit mutual short-circuiting engagement between one set of corresponding edge portions of the larger elements which are normally out of engagement, and means for causing successive mutual engagement of said set of edge portions without changing substantially the contact pressure between said carbon and metal elements.

3. A variable resistance comprising a pile of electrical conducting elements of alternately different sizes and different materials between which there is a relatively high contact resistance, one set of non-adjacent elements being so arranged that they permit mutual engagement between portions of the larger elements, variable pressure applying means for urging said portions toward mutual engagement and separate relatively low resistance means permanently interconnecting the contact faces of each of said portions, said variable pressure applying means acting to cause mutual engagement of said separate relatively low resistance means.

4. A variable resistance comprising a pile of alternate carbon and metal elements, the elements of one material being smaller than the elements of the other material and being so aligned that the smaller elements will permit mutual engagement between one set of corresponding edge portions of the larger elements, separate aligned silver inserts passed through each of said corresponding edge portions, and variable pressure applying means for causing mutual engagement of said silver inserts.

5. A variable resistance comprising a pile of electrical conducting elements of alternately different materials between which there is a relatively high contact resistance, the odd numbered elements being of a different size than the even numbered elements, the smaller elements being aligned so that they are intermediate one set of opposite edge portions of the larger elements, insulating means between the edge portions of said larger elements on one side of said smaller elements, separate low resistance means for each of the larger elements for interconnecting their contact faces at the edge portions thereof on the other side of said smaller elements, and variable pressure means for rocking said larger elements about said smaller elements for selectively causing engagement of the edge portions of the larger elements on said opposite sides of the smaller elements.

6. A variable resistance comprising a pile of alternate carbon and metal elements, each element of a given group of like elements being provided with means for establishing a relatively low resistance contact between each pair of like elements at one end and a relatively high resistance contact between each pair of like elements at the opposite end, one element of the other group of said elements being arranged between each pair of elements of said given group intermediate said high and low resistance ends so as

to act as a pivot about which said elements of said given group may be rocked from contact at one end to contact at the opposite end, and means for successively rocking the elements of said given group from one end to the other.

7. A variable resistance comprising a pile of alternate metal and carbon elements, the elements of one material being smaller than the elements of the other material and being placed intermediate the edge portions of the larger elements, insulating material placed between one set of corresponding edge portions of said larger elements, and means for applying a variable pressure to said pile in such a way that for one degree of pressure one set of corresponding edge portions of said larger elements are pressed together and for another degree of pressure the other set of corresponding edge portions of said larger elements are pressed together.

8. A compressible pile resistance including a plurality of carbon elements having corresponding portions thereof permanently short circuited, corrosion-resistant metal elements inserted alternately between corresponding non-short-circuited portions of said carbon elements, and means for causing successive engagement with said short-circuited portions so as progressively to decrease the resistance of said pile.

9. A compressible pile type resistance comprising a stack of carbon plates, aligned metal inserts between said plates for providing a relatively high alternate metal-to-carbon and carbon-to-metal surface contact resistance path through said stack, said metal inserts being small compared with the size of said plate so that said plates may be rocked about said inserts as effective pivots, aligned means for reducing to a relatively low value the resistance between corresponding portions of opposite contact faces of said carbon plates, and means for compressing said stacks on a line through said last mentioned means whereby said plates are progressively rocked about said effective pivots thereby progressively bringing said resistance reducing means into engagement so that said metal-to-carbon and carbon-to-metal surface contact resistances are progressively short-circuited.

10. A compressible pile type variable electrical resistance comprising a stack of similar carbon pile plates, metal inserts between said plates, said insert being small compared with the size of said plates so that said plates may be rocked about said inserts as effective pivots, separate means for providing a relatively low resistance electrical conducting path between opposite contact faces of a corresponding end of each of said plates, and means for applying a compressing force to said stack along a line through said means.

11. A compressible pile resistance including a plurality of carbon plates arranged in a stack, said plates being thicker in the middle than at the ends, corresponding ends of each of said plates being short circuited, metal plates inserted between the other ends of said carbon plates, the thickness of said metal plates being less than the difference in thickness of the end and middle portions of said carbon plates, and means for rocking said carbon plates about their thickest portions so as to provide a three-step variable resistance current path through said pile, said three steps comprising, first, a high resistance metal-to-carbon contact path, second, an intermediate resistance carbon-to-carbon contact path and, third, a low resistance metal-to-metal contact path.

12. A compressible pile resistance comprising a plurality of carbon plates arranged in a pile, each of said plates being slightly thicker in the middle than at the ends, corresponding ends of said plates being metal coated, oxidation and corrosion resisting metal plates inserted between the other ends of said carbon plates, means for applying a given pressure to said pile along a line through the ends of said carbon plates between which said metal plates are inserted, and means for applying a variable pressure to said pile on a line through the coated ends of said pile.

13. A compressible pile resistance comprising a plurality of carbon plates arranged in a pile, each of said plates being thicker in the middle than at the ends, silver plating on corresponding ends of said plates, chromium-nickel-iron alloy plates inserted between the other ends of said carbon plates, resilient means for pressing together the ends of said carbon plates between which said alloy plates are inserted, and variable pressure producing means for compressing the plated ends of said carbon plates together.

14. A compressible pile type variable electrical resistance comprising a stack of similar carbon plates, metal inserts between said plates, said inserts being small compared with the size of said plates and being placed intermediate the ends of said plates, relatively poor electrical conducting means interposed between the ends of said plates at one end of said stack and separate relatively good electrical conducting means connecting the opposite contact faces of each of said plates at the opposite end of said stack.

15. In combination, a plurality of similar relatively thin elongated substantially rectangular carbon plates arranged uniformly in a vertical stack, a corresponding pair of relatively closely spaced notches in each of the longer sides of each of the plates, said corresponding pairs of notches being equally nearer one end of their respective plates than the other, relatively thin rectangular metal members interleaved transversely between said plates, said members each having an upwardly and a downwardly bent extension on each end for insertion respectively in the notches of the plates which are above and below them whereby said plates are held in alignment, relatively poor electrically conducting elements interposed between the ends of said plates farthest from said transversely interleaved metal members, and individual silver rivets passed through the ends of said plates nearest to said members.

16. In a variable electrical resistance device, a stack of alternate relatively large metal elements and relatively small carbon elements, and means for varying the resistance of said stack by successively rocking said metal elements on said carbon elements until successive short circuits are completed around the metal-to-carbon surface contact resistances making up the resistance of said device.

17. In a variable electrical resistance device, a stack of alternate relatively large metal elements and relatively small carbon elements, means for varying the resistance of said stack by successively rocking said metal elements on said carbon elements until successive short circuits are completed around the metal-to-carbon surface contact resistances making up the resistance of said device, and cut away openings in said metal elements for facilitating the passage of air for cooling said device.

18. In a variable electrical resistance device, a stack of alternate relatively large metal elements

and relatively small carbon elements, insulating members between said metal elements on one side of said carbon elements, means urging said insulating members together, and means for applying a compressing force to said metal elements on the other side of said carbon elements whereby said metal elements will be rocked on said carbon elements so as successively to short circuit the metal-to-carbon surface contact resistances making up the resistance of said device.

19. In a variable electrical resistance device, a stack of alternate relatively large metal elements and relatively small carbon elements, insulating members between said metal elements on one side of said carbon elements, means urging said metal elements against said insulating members, contacts set in said metal elements on the other side of said carbon elements, and means for applying a compressing force to said metal elements on the side of the carbon elements on which said contacts are whereby said metal elements will be rocked on said carbon elements so as successively to short circuit the metal-to-carbon surface contact resistances making up the resistance of said device by the successive engagement of said contacts.

20. In a variable electrical resistance device, a stack of alternate large and small elements between adjacent faces of which there is a relatively high contact resistance, and means for varying the resistance of said stack by successively rocking said large elements on said small elements until successive low resistance paths around said relatively high contact resistances are established by the engagement of said large elements.

21. In a variable electrical resistance device, a stack of electrical conducting elements in which between faces of adjacent elements there is a relatively high contact resistance and in which between faces of non-adjacent elements there is a relatively low contact resistance, and means for varying the resistance of said stack by successively rocking the non-adjacent elements between which there is a low contact resistance about the intermediate elements whereby the relatively high contact resistances between adjacent elements are successively effectively short circuited.

22. In a variable electrical resistance device, a stack of alternate carbon and metal elements between which there is a relatively high contact resistance, and means for varying the resistance of said stack by successively rocking the elements of one set of non-adjacent elements about the other elements until portions of the rocked elements engage each other, the contact resistance between said rocked elements being less than the contact resistance between adjacent elements.

23. In a resistance regulator, a support which is subject to being tilted, a plurality of similar variable resistance stacks mounted on said support, each of said stacks comprising a plurality of tiltable electrical conducting elements, means for normally simultaneously varying the resistance of said stacks by tilting said elements, the resistance of each of said stacks having opposite variations as said support tilts in opposite directions from a normal position by reason of an inherently responsive tilting of the elements thereof, a circuit including said stacks serially connected therein, said stacks being so oriented on said support that

the individual resistance changes of said stacks when said support tilts will oppose each other's effects on the total resistance of said circuit whereby the action of said resistance varying means is substantially independent of normal variations in the position of said support.

24. A wide range variable electrical resistance comprising, in combination, a plurality of resistance elements arranged to form a series electrical conducting path having a relatively high electrical resistance, a plurality of electrical conducting members the specific contact resistance between which and said resistance elements is higher under similar pressure conditions than the specific contact resistance between said resistance elements themselves interleaved between said resistance elements in order to increase the resistance of said path, means for decreasing the resistance of said path including a plurality of contacts between which the specific contact resistance is less under similar pressure conditions than the contact resistance between said resistance elements connected so that by their successive engagement they will short-circuit separate contact resistances in said path, and means for causing cumulative engagement and disengagement between said contacts by producing a successive relative tilting motion between said resistance elements and said conducting members.

25. A wide range variable electrical resistance comprising, in combination, a plurality of resistance elements arranged to form a series electrical conducting path having a relatively high electrical resistance, a plurality of electrical conducting members the specific contact resistance between which and said resistance elements is higher under similar pressure conditions than the specific contact resistance between said resistance elements themselves interleaved between said resistance elements in order to increase the resistance of said path, means for decreasing the resistance of said path including a plurality of contacts between which the specific contact resistance is less under similar pressure conditions than the contact resistance between said members connected so that by their successive engagement they will short-circuit separate contact resistances in said path, and means for causing cumulative engagement and disengagement between said contacts by producing a successive relative tilting motion between said resistance elements and said conducting members.

26. In a variable resistance device, a stack of electrical conducting elements having contacting surfaces between which relatively high specific contact resistances exist, a plurality of contacts between engageable faces of which the specific contact resistance is relatively low compared with the specific contact resistance between said elements, and means for causing said contacts cumulatively effectively to short-circuit separate contact resistances between said elements, said elements being composed of such alternately different materials that the contact resistances between them decrease substantially instantaneously and independently of changes in their temperature as current through them increases whereby the life of said contacts is substantially increased and radio interference resulting from sparking of said contacts is substantially reduced.

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