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MAY 18, 1943.
BY A. P. C.

R. SCHADE
VARIABLE RESISTORS
Filed June 10, 1940

Serial No.
339,725
3 Sheets-Sheet 1

Fig. 1

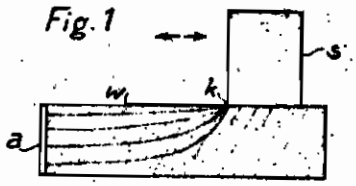

Fig. 2

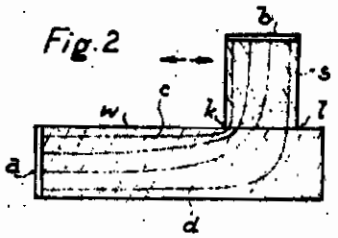

Fig. 3

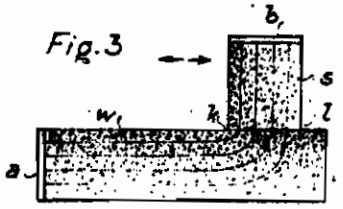

Fig. 4

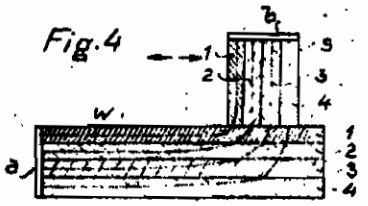

Fig. 5

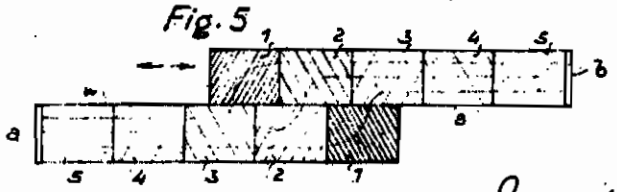

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Fig. 6

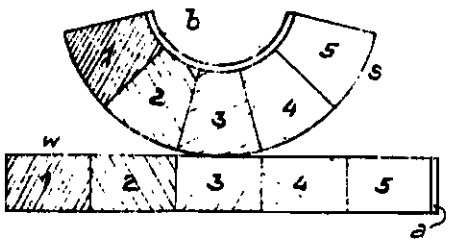

Fig. 10

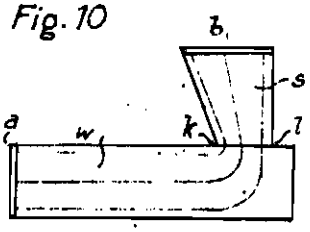

Fig. 7

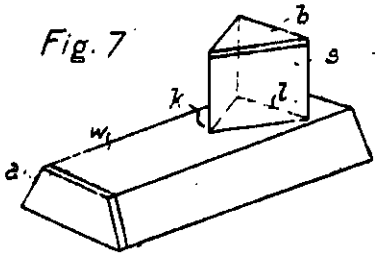

Fig. 11

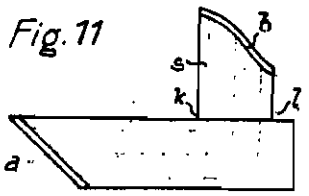

Fig. 8

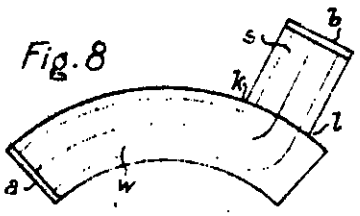

Fig. 12

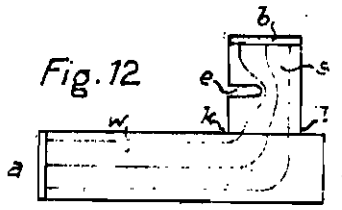

Fig. 9

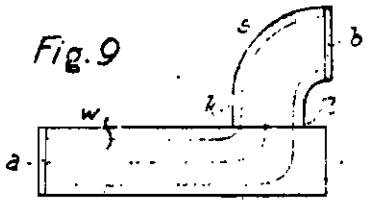

Fig. 13

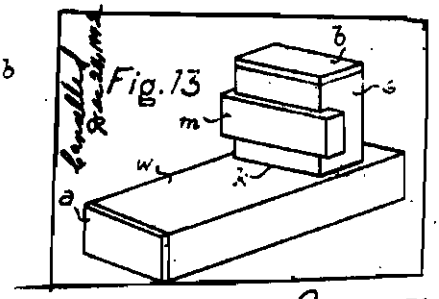

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Fig. 14

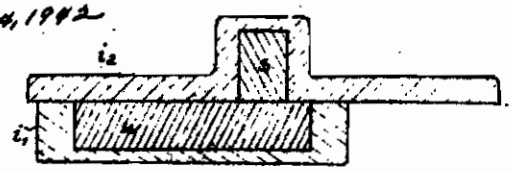


Fig. 15

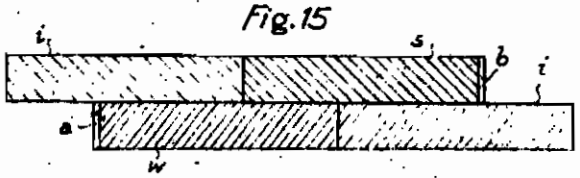


Fig. 16

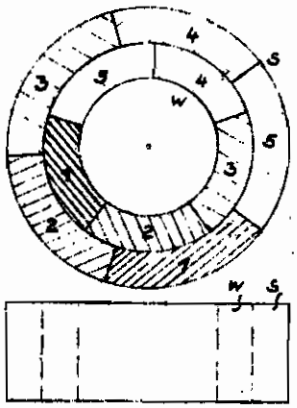


Fig. 17

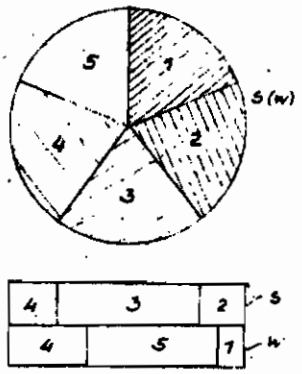
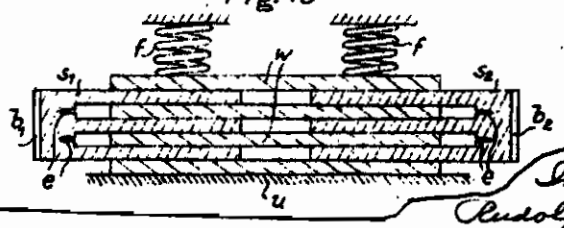


Fig. 18



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ALIEN PROPERTY CUSTODIAN

VARIABLE RESISTORS

Rudolf Schade, Finkenkrug, Osthavelland, Germany; vested in the Alien Property Custodian

Application filed June 10, 1940

The invention relates to variable resistors having a contact cooperating with the resistor and which instead of the switch devices hitherto known are to be employed alone or in connection with residual current circuit breakers to interrupt power circuits. Such resistors carry a very high load and must be varied very rapidly, so that disturbing influences occur at the contact surface which may so unduely stress the resistor and contact as to damage them within a short time. These influences are on the one hand the cause of unduely high current densities with subsequent excessive heating and wear and tear, particularly at one edge of the contact, and on the other hand of a sparking at this edge with similar consequences. According to the invention such influences are avoided by suitable means.

The current is caused according to the invention to flow along such paths in the resistor, contact or in both parts as to prevent an undue crowding of the current paths at one edge of the corresponding contact surface. Fig. 1 of the drawings illustrates the undesired crowding of the current paths if the contact *s* consists as is usual entirely of metal. If the conductivity of the contact is indefinitely great as compared to the resistor *w*, the current paths are crowded at the edge *k* of the contact *s* spaced from the current junction *a* even if they enter the resistor at the current junction *a* uniformly distributed. The current density is also indefinitely great at the current junction. This is due to the unequal length of the current paths along the upper and lower side of the resistor. The detrimental effects mentioned above are already brought about upon merely approaching the theoretical limit illustrated in the drawing, that is to say, in the case of the definite conductivity of the usual metal contacts.

According to the invention the crowding of the current paths is prevented either by suitably selecting or distributing the specific resistance of the resistor, contact or of both parts, also by giving the one or the other part a suitable shape, further by suitably distributing the contact resistance over the corresponding contact surface as well as by suitably distributing the contact pressure over this surface or by selecting and distributing the conductive resistance. The means, whereby this may be accomplished, may also be combined in various ways.

The resistance in the different current paths may be made equal to a certain extent, if the contact and resistor are made of the same material. The distribution of the current paths thereby obtained is roughly illustrated in Fig. 2. In this case the contact edge *k* carries a considerably smaller load than according to Fig. 1, this, however, being disadvantageous for certain instances. The resistance in the current path *c* extending along the upper surface of the resistor *w* and the left-hand surface of the contact *s* is smaller than that in the current path *d* extending near the lower surface of the resistor *w* and near the right-hand surface of the contact *s*. A greater current density will therefore be brought about in the neighborhood of the left-hand contact edge *k* than in the neighborhood of the edge *l*. Consequently, the resistance in the different current paths between the two current junctions or terminals *a* and *b* of the resistor *w* and contact *s* respectively is rendered according to the invention as uniform as possible.

An effective improvement is obtained if the specific resistance of the contact varies along the surface in engagement with the resistor. Also a variation of the specific resistance of the resistor contributes in bringing about the same resistance in the different current paths. The stipled surface illustrated in Fig. 3 indicates according to the invention the variations of the specific resistance of the resistor *w* and contact *s*, the points at which the dots are more crowded indicating a greater resistance. Along the contact surface the specific resistance of the resistor *w* is greatest. The current flowing from the current junction *a* tends therefore to follow paths towards the lower side of the resistor, i. e., away from the dangerous point *k*. By increasing the specific resistance of the contact *s* with respect to its edge *k* the current paths may also be shifted away from this edge so as to prevent an undue current density at this edge.

The specific resistance of the contact and that of the resistor may also vary according to the same law along the surface serving for the passage of the current, so that the drop of the specific resistance is approx. the same in both bodies.

Fig. 4 shows an embodiment of the invention which is somewhat less complicated than the non-homogeneous bodies *w* and *s* according to Fig. 3. These bodies consist as shown in Fig. 4 of individual layers 1 . . . 4 of different specific resistance, the different shadings indicating a distribution of the specific resistance and of the current path as illustrated in Fig. 3.

The change in resistance is also adapted to the manner in which the contact moves. If the con-

tact slides on the resistor it may be preferable to uniformly vary in opposite directions the specific resistance of both parts along the surface serving for the passage of the current. Fig. 5 shows such an embodiment in which the contact is designed as is also the resistor in the form of a rod or plate. Both bodies consist of sections 1 . . . 5 of a different specific resistance, arranged in opposite sequence. As will be seen from the current paths shown in Fig. 5 the distribution of current at the contact surface is symmetrical with respect to the center of the latter. Consequently, an undue current density cannot occur at this edge. The main portion of the current passes between parts of the same specific resistance (here, for instance, between 2—2). It would even suffice when giving the resistor and contact the same shape to make both parts of approx. the same material having the same specific resistance, since also the symmetry of the distribution of current is then ensured. The form of the invention shown in Fig. 5 is, however, more advantageous, since the specific resistance at the outer edges of the two parts sliding on one another is greatest and an undesired increase in current density is avoided at these points. The two parts *w* and *s* may be moved in opposite directions in order to increase the control speed.

If the resistor and contact or one of these bodies is given a cylindrical shape, i. e., the one body rolls on the other, the specific resistance along the rolling surface serving for the passage of the current may vary preferably in the same direction along this surface. The rolling body consists, for instance, as shown in Fig. 6 of sectors 1 . . . 5 of different specific resistance. Both the resistor and the contact are preferably subdivided into sections of different resistances. In this case the arcs of the sectors of the rolling body should be equal to the lengths of the sections of the resistor, so that only parts of equal specific resistance come into contact. Consequently, the specific resistance in the contact increases in the same direction as that in the resistor.

Figs. 7 to 12 show further instances for preventing an undue crowding of the current paths or at least their causes by giving the bodies employed a suitable shape.

The shape may be given either by varying the cross-section or the longitudinal section of the resistors or contacts.

According to Fig. 7 the cross-section of the resistor and contact is enlarged at the outer side of the angle or arc formed by the current paths. The apex of said angle coincides with the edge of the contact. About this edge the current paths are bent in an angle- or arc-like manner as will be seen, for instance, from Figs. 2 to 4. Since the innermost current path with respect to the edge *k* is the shortest, the width of the resistor and contact is smallest at this point according to Fig. 7 and is enlarged towards the opposite cross-section edge *l*. The center of gravity of the current carrying cross-section is thereby shifted from the dangerous point and the heat produced is therefore more uniformly distributed. Furthermore, the point *k* of the greatest current density is best cooled.

In the following embodiments the resistors, contacts or both are given such a shape in the longitudinal section that the current paths have the same length. According to Fig. 8 the longitudinal section of the resistor *w* and according to Fig. 9 of the contact *s* is so curved that the center of curvature is opposite to the current junction of the other part. In this manner the current path lying near the edge *k* is lengthened and a concentration of the current in this path is prevented. According to Fig. 10 the longitudinal section of the contact has a wedge-like shape, whereby the current path in said section extending near the edge *k* is longer than that extending near the edge *l*. Also this contributes to bring about a uniform distribution of current in the contact cross-section. A similar shape may also be given to the resistor *w*. In order to attain the same length of the current paths the surfaces *a* and *b* of the resistor *w* and contact *s* may be inclined with respect to the central current path in these bodies and, if desired, curved in a suitable manner, as will be seen from Fig. 11. A similar effect may be attained according to Fig. 12 by the fact that the current paths at the inner side of the angle or arc formed by the same are lengthened, for instance, by notches *e* provided in the contact *s*. All the embodiments described above may be combined in any suitable manner.

If the distribution of current in the contact surface is to be rendered uniform by the selection of the contact resistance, the contact resistance at the edge *k* of the contact near the current junction *a* of the resistor must be made greater than that at the opposite edge *l*. The contact resistance must decrease uniformly or gradually towards the edge *l* in order that the current paths be shifted away from the dangerous edge *k* of the contact. The contact resistance may be influenced by suitably machining the brush surface in contact with the resistor, by metal or insulating material coatings suitably distributed over this surface or in any other suitable manner.

The distribution of current over the contact surface may be further influenced by gradually increasing the contact pressure on this surface. The contact pressure is preferably smallest at the edge *k* of the contact *s* and increases towards the opposite edge *l*. This may be effected in a simple manner by an asymmetrical current load of the contact according to the invention. The contact depending upon the manner in which it is secured to its support may be subjected to a tilting moment which tends to tilt it about the edge *l*.

The current paths may be influenced by suitably selecting and distributing the inductive resistance as will be seen from Fig. 3 with the aid of magnetically conducting bodies *m* which surround at the inner side of the angle formed by the current paths a portion of the current-carrying cross-section of the resistor *w* or contact *s*. The current paths which traverse the inner space of the horse-shoe shaped body *m* having a greater inductive resistance, since the intensity of the field interlinked therewith is increased. Also in this arrangement the current paths are shifted into the cross-section portion having a smaller inductive resistance and are partly kept away from the dangerous edge *k*. A similar effect may also be obtained by adding magnetic material to the resistor or contact. The material must be distributed in a similar manner as the particles of higher specific resistance according to Fig. 3 or arranged in layers as shown in Fig. 4.

According to the invention also provisions must be made besides the means described above to

suppress a sparking of the contact. Since the undesired sparking contributes also to heat up particularly the edge *k* of the contact, a suppression of the sparking supports the action of the means so far described in such a manner that the reliability of operation of the regulating device is enhanced and the life of the parts subjected to wear is considerably lengthened.

Means for suppressing the sparking of the contacts are well known. However, such means are employed according to the invention on an entirely new principle, whereby the abovementioned advantage are obtained. It is, for instance, also well known to reduce the sparking at the contact points by grinding the contact surface of the bodies to such an extent that an interstice of the order of magnitude of 0.01 mm is left therebetween. The limit for the permissible width of this interstice amounts to about 0.02 mm at contact points exposed to the air. (Paschen ignition voltage curve). The grinding operation may be less accurately effected or the interstice may be wider if the sparking is suppressed by other measures, for instance, by embedding the contacts in a medium which suppresses the sparking.

By a rapid change of the resistance value and of the current flowing through the resistor additional voltages occur across the resistor which support flash-overs exteriorly of the contact points, thus deteriorating also the bodies employed. Furthermore, the dangerous edge *k* is indirectly heated. The liability of operation of the regulating device may be therefore also increased by covering the resistor, the contact or both in such a manner with insulating material that flash-overs are prevented at the outer side of these bodies. The covering with insulating material is prefcrably effected in the manner that the resistor and the contact are completely surrounded by insulating bodies. In Fig. 14 *w* denotes the resistor, *s* the contaoct, i_1 the insulating body surrounding the resistor *w* and i_2 the insulating body surrounding the contact *s*. The two insulating bodies cover the surfaces for the passage of current, provided that these surfaces are not being employed for the passage of current.

The resistor *w* and contact *s* may also be so arranged without the outer covering of insulating material when employing insulating pieces *i* as shown in Fig. 15 that parts of the surface serving for the passage of the current are not uncovered in any position.

Also the resistor and contact may be so arranged that they completely cover in relation to one another the surfaces serving for the passage of current. As will be seen from Fig. 16 the said two bodies form hollow cylinders arranged the one within the other and which may consist as the resistor and contact shown in Fig. 5 or 6 of the individual sectors 1 . . . . 5 of different specific resistance. The points from which the current is taken are preferably arranged at the opposite ends of both hollow cylinders. According to Fig. 17 the resistor and the contact are formed of two discs which also consist of sectors 1 . . . . 5 of different specific resistance. For the control, the hollow cylinders according to Fig. 16 and the discs according to Fig. 17 are rotated with respect to one another. Since the surface for the passage of the current has no uncovered parts, also no appreciable sparking—particularly in the case of a smooth grinding—can occur at this surface. The outer surfaces of the hollow cylinders and discs may be covered with insulating material. The current junctions are to be arranged on the sectors of the smallest resistance denoted by the numeral 5.

As already mentioned the sparking may be further suppressed by embedding the variable resistors in a suitable medium. The resistor may be arranged in vacuum or in a medium of considerable disruptive strength (oil or the like) which suppresses the sparking.

To relieve the current junction to a further extent it is preferable to subdivide the junction into various parallel or series-connected junctions. Depending upon the voltage or current to be controlled the parallel or series connection is to be employed. It may be of advantage to combine the parallel connection and series connection of current junctions or regulating elements. An instance for a particular type of parallel connection of current junctions is shown in Fig. 18. The resistor *w* and contact *s* engage one another in a comb-like manner, whereby the contact surface is considerably increased. The contact as well as the resistor consist of various parallel-arranged rods or plates which are slidably arranged between the parts of the resistor. In this case also the resistor and contact may be designed in the same manner so that two resistors consisting of parallel plates or rods may come into engagement with one another in a comb-like manner by shifting the one with respect to the other. Various contacts s_1, s_2 which move in opposite directions may also be arranged on resistance plates *w* as shown in Fig. 18. The plates of the resistors *w* are loosely arranged one upon the other and are pressed together and against the support *u* by means of springs *f*. In order that the projections of the contacts s_1 or s_2 may follow the pressing of the resistance plates they are separated from one another except for a web carrying the current junction b_1 or b_2. The parts of the embodiment shown in Fig. 18 may be designed in a manner similar to that shown in Figs. 3, 4 or 5, i. e., the specific resistance of the contact and resistor may also vary along the surface serving for the passage of the current.

RUDOLF SCHADE.