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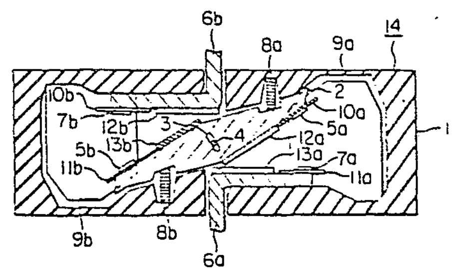
(54) A current limiter.

(57) The present invention relates to a current limiter wherein a pair of conductors (2, 6a, 6b) each having a contact (5a, 5b, 7a, 7b) fastened thereto are arranged in opposition to each other so that the senses of currents to flow through the respective conductors (2, 6a, 6b) via the contacts (5a, 5b, 7a, 7b) may become opposite to each other, and wherein the respective contacts (5a, 5b, 7a, 7b) are surrounded with arc shields (10a, 10b, 11a, 11b). The arc shields (10a, 10b, 11a, 11b) are formed of a highly resistive material having a resistivity higher than that of the conductors (2, 6a, 6b), and they effectively inject the metal particles of the contacts (5a, 5b, 7a, 7b) into an electric arc struck thereacross, to rapidly and greatly raise an arc voltage and to enhance the current limiting performance of the current limiter.

FIG. 3



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" A CURRENT LIMITER "

The present invention relates to a current limiter for protecting electric circuits. More particularly, the invention as claimed is intended to provide a novel current limiter in which make-and-break contacts are surrounded with arc shields so as to rapidly and greatly raise the arc voltage of an electric arc struck across the contacts, thereby to attain an effective current-limiting function.

In prior current limiters, an electric arc struck across contacts expands its feet (base) to the parts of conductors around and near the contacts. This leads to the disadvantage that it is difficult to generate a high arc voltage, and that a statisfactory current-limiting function cannot be achieved.

The present invention consists in a current limiter in which a pair of conductors having respective contacts fastened thereto are arranged in opposition to each other, and in which the contacts are provided with arc shields surrounding them. The arc shields are formed of a highly resistive material having a resistivity higher than that of the conductors and which effectively injects the metal particles of the contacts into an electric arc struck across these contacts, thereby to rapidly and greatly raise the arc voltage of the electric arc so as to enhance the current-limiting performance of the current limiter. Preferred ways of carrying out the invention are described below with reference to drawings, in which: -

Figure 1a is a sectional plan view of a conventional current limiter to which the present invention is applicable;

Figure 1b is a sectional plan view showing the state in which the contacts of the current limiter in Figure 1a are separated;

Figure 2 is a model diagram showing the behavior of an electric arc which is struck across the contacts of the current limiter in Figure 1a;

Figure 3 is a sectional plan view showing an embodiment of a current limiter according to the present invention;

Figure 4 is a perspective view showing the relationship between a contact and an arc shield for use in the current limiter according to the present invention;

Figure 5 is an electrical connection diagram showing an example in which the current limiter according to the present invention is used for an electric circuit;

Figure 6 is a model diagram showing the action of the arc shields for use in the current limiter according to the present invention;

Figure 7 is a sectional plan view of another conventiona current limiter of a type different from that of the current limiter in Figure 1a, to which the present invention is also applicable;

Figure 8 is a sectional plan view showing another embodiment of the current limiter according to the present invention; and

Figure 9 is a sectional plan view showing still another embodiment of the current limiter according to the present invention.

In the drawings, the same symbols indicate identical or corresponding parts.

A conventional current limiter to which the present invention is applicable will be described with reference to Figures 1a and 1b. In the drawings, numeral 1 designates a casing which is molded of an electrically insulating material. A rotary contactor 2 is disposed inside the casing 1 in a manner to be turnable about a pivot pin 4 which is inserted in an elliptical hole 3 penetrating through the rotary contactor in the position of the center of gravity thereof. Movable contacts 5a and 5b are disposed at both the ends of the rotary contactor 2 in the diametrical direction thereof. Inside the casing 1, there are arranged stationary contactors 6a and 6b which pass through the walls of the casing. The stationary contactors 6a and 6b are respectively provided at their ends with stationary contacts 7a and 7b which fall within the loci of rotation of the movable contacts 5a and 5b of the rotary contactor 2. In the normal condition, the movable contacts 5a and 5b are respectively held against the stationary contacts 7a and 7b under a required pressure by means of springs 8a and 8b. Parallel current paths close to each other are formed by the mutually opposing longitudinal parts of the two stationary contactors 6a and 6b and the rotary contactor 2, that is, parts 6a1 and 2a and parts 6b1 and 2b. Electric arcs which are struck across contacts 5a and 7a and across contacts 5b and 7b when they are separated from each other, are respectively stretched and cooled and then extinguished by arc extinguishing chambers 9a and 9b which are defined in the casing 1.

In the normal condition the current limiter constructed as explained above, the rotary contactor 2 has its longitudinal parts 2a and 2b located in opposition to the longitudinal parts 6a1 and 6b1 of the stationary contactors 6a and 6b, respectively, as shown in Figure 1a. Accordingly, it forms the two sets of parallel current paths in which the senses (polarities) of currents flowing through the opposed longitudinal parts are opposite to each other. Therefore, when a current in excess of a predetermined value flows through this current limiter, the rotary contactor 2 receives counterclockwise turning forces based on electromagnetic repulsive forces induced between it and the two parallel stationary contactors 6a and 6b, and the urning forces separate the two sets of contacts 5a and 7a and 5b and 7b against the respective springs 8a and 8b. Thus, the electric arcs are struck across the contacts. The arcs are cooled and split and then extinguished by arc extinguishing plates which are disposed in the arc extinguishing chambers 9a and 9b. Herein, the current limiter shown in Figures 1a and 1b has the feature that the operation of separating the contacts can be promptly effected because the two repulsive forces in the same directions act on the rotary contactor 2 at the same time.

With the prior current limiter described above, however, the arc voltage of the electric arc across each set of contacts is structurally limited to a certain value, and the current limiting effect is not fully satisfactory. Hereunder, the circumstances of the operation of both contacts will be described.

In general, the arc resistance has the following relationship:

$$R = \rho \frac{l}{S}$$

where R : arc resistance (Ω)

ρ : arc resistivity ($\Omega \cdot$ cm)

l : arc length (cm)

S : arc sectional area (cm^2)

In general, in a short arc which has a high current of at least several kA and the arc length of which is at most 50 mm, the arc space is occupied by the particles of the contacts. The emission of the contact particles occurs orthogonally to the surfaces of the contacts. At the emission, the particles have a temperature close to the boiling point of the metal material of the contacts. Further, as soon as the particles are emitted into the arc space, they undergo the injection of electrical energy to be rendered high in temperature and pressure and to bear an electric conductivity, and they flow or fly away from the contacts at high speed while expanding in a direction conforming with the pressure distribution of the arc space. In this manner, the arc resistivity ρ and the arc sectional area S in the arc space are determined by the quantity of the contact particles produced and the direction of emission thereof. Accordingly, the arc voltage is determined by the behavior of such contact particles.

Now, the behavior of the contact particles in the prior current limiter will be described with reference to Figure 2. In Figure 2, surfaces X are opposing surfaces which serve as contact surfaces when the respective contacts 5a and 7a come into touch, while surfaces Y include those surfaces of the contacts which are electrical contact surfaces other than the opposing surfaces X and parts of the surfaces of the conductors of the contactors. A contour Z_1 indicated by a dot-and-dash line in Figure 2 is the envelope of the arc struck across the contacts 5a and 7a. Further, symbols p_1, p_2 and p_3 indicate the emitted particles. More specifically, the particles p_1 are the contact particles emitted from near the centers of the opposing surfaces X, the particles p_2 are the contact and conductor particles emitted from the surfaces Y which include the contact surfaces and the parts of the conductor surfaces of the contactors 6a and 2 as stated above, and the particles p_3 are the contact particles emitted from those positions near the peripheral edges of the opposing surfaces X which are intermediate the positions of the contact particles p_1 and p_2. The paths of the particles p_1, p_2 and p_3 after the emission extend along flow lines indicated by arrows m, n and o_1, respectively.

The contact particles p_1, p_2 and p_3 thus emitted have their temperature raised from the boiling point of the metal of the contacts, i.e., approximately 3,000°C, to a temperature at which the particles bear an electric conductivity, i.e., at least 8,000°C, or to a still higher temperature of approximately 20,000°C. Therefore, the particles take energy out of the arc space and lower the temperature of the arc space, with the result that an arc resistance is generated. The quantity of energy which the contact particles take out (absorb) of the arc space is greatly affected by the extent of the temperature rise of the particles. In turn, the extent of the temperature rise is determined by the positions and emission paths in the arc space, of the electrode particles emitted from the contacts. In consequence, in the prior current limiter shown in Figure 2, the contact particles p_1 emitted from near the centers of the opposing surfaces X take large quantities of energy out of the arc space, but the conta particles p_2 emitted from the surfaces Y including the aforementioned contact surfaces and the parts of the conductor surfaces deprive the arc space of smaller quantities of energy than those of the contact particles p_1. In addition, the contact particles p_3 emitted from the peripheral parts of the opposing surfaces X can take out only intermediate quantities of energy between the quantities of energy which the contact particles p_1 and p_2 absorb. That is, in the range in which the contact particles p_1 flow, the large quantities of energy are taken out to lower the temperature of the arc space, so that the arc resistivity ρ is increased. However, in the range in which the contact particles p_2 and p_3 move, the temperature of the arc space is lowered little because large quantities of energy are not taken out. Accordingly, the increase of the arc resistivity ρ cannot be achieved. Moreover, since the arc is generated from the opposing surfaces X and the contact surfaces Y, the arc sectional area increases, resulting in a lowered arc resistance.

Such outflow of energy from the arc space as caused by the contact particles balances with the electrical injection energy. It is therefore understood that, when the contact particles generated across the contacts are farther injected into the arc space, naturally the temperature of the arc space is more lowered, with the result that the arc resistivity can be increased to raise the arc voltage.

Figure 3 shows an embodiment of a current limiter according to the present invention. Referring to Figure 3, the contacts 5a and 5b of the rotary contactor 2 are respectively surrounded with arc shields 10 and 10b, while the contacts 7a and 7b of the stationary contactors 6a and 6b are respectively surrounded with arc shields 11a and 11b. Symbols 12a and 12b indicate pieces of an insulating material which cover the conductor surfaces or bare charging parts of the rotary contactor 2 opposing to the stationary contactors 6a and 6b, respectively, while symbols 13a and 13b indicate pieces of the insulating material which similarly cover the bare charging parts of the stationary contactors 6a and 6b, respectively. The other parts are the same as in the prior construction shown in Figures 1a and 1b.

All the arc shields 10a, 10b, 11a and 11b are formed of a highly resistive material which has a resistivity higher than that of the base conductor, for example, an organic or inorganic insulator, or a highly resistive metallic material such as nickel, iron, copper-nickel, copper-manganese, manganin, iron-carbon, iron-nickel, and iron-chromium. As methods for forming the arc shields, there are a method in which a plate-shaped member fabricated of the highly resistive material is snugly fitted and fixed to the contact part as typically illustrated by the mounting state of the arc shield 11a on the contact 7a of the stationary contactor 6a in Figure 4, and a method in which the conductor surface is coated with a highly resistive material such as ceramic by, for example, the plasma jet spraying. According to the latter method based on the coating, the arc shields can be formed inexpensively and simply. Especially, the weight of the arc shields on the rotary contactor side becomes light. This brings forth the advantage that the moment of inertia becomes small to increase the contact separating speed and to raise the arc voltage. In the present embodiment, the arc shield is formed with a plate shape. This is because it is effective to confine the arc, as will be described later.

Figure 5 shows a diagram of electrical connection wherein a resistor 15 is disposed in parallel with an electric circuit for which the current limiter 14 shown in Figure 3 is used. In this circuit arrangement, the resistor 15 is short-circuited during the engagement of the contacts of the current limiter, whereas it is inserted in the electric circuit during the separation of the contacts. In addition, when the arc resistance of the electric arc struck across the contacts exceeds the resistance of the resistor 15, the current of the circuit turns over to the resistor 15. Therefore, the resistor 15 is effective to extinguish the arc.

Now , the behavior of the contact particles will be described with reference to Figure 6 in order to explain the effect of the arc shield employed in the embodiment of Figure 3. In Figure 3, symbols X, p_1, p_3 and m correspond to those indicated in Figure 2, respectively. Symbol Z_2 indicates the envelope of the arc space shrunk by the device of the present invention, and symbol O_2 the flow line of the contact particle p_3 flowing or moving along a path different from that in the prior device. Parts Q indicated by crosshatching are spaces in which the pressure generated by the electric arc is reflected by the arc shields 10 and 11a, thereby to raise the pressure which has been lowered in the prior device without arc shield.

According to such construction, pressure values in the spaces Q cannot exceed the pressure value of the space of the arc itself, but much higher values are exhibited at least in comparison with values in the case where the arc shields are not provided. Accordingly, the considerably high pressures in the spaces Q caused by the arc shields 10a and 11a afford forces suppressing the spread of the space of the arc and confine the arc within a small space. This results in constricting and confining into the arc space the flow lines of the contact particles p_1 and p_3 emitted from the opposing surfaces X. Therefore, the contact particles emitted from the opposing surfaces X are effectively injected into the arc space. As a result, large quantities of contact particles deprive the arc space of large quantities of energy as compared to the prior device. Therefore, the arc space is remarkably cooled, to considerably increase the arc resistivity or arc resistance R and to greatly raise the arc voltage.

Further, when at least one of the opposing conductor surfaces of the rotary contactor and the stationary contactor is covered with the insulating material as in the embodiment shown in Figure 3, dielectric breakdown in any other place than the contacts is prevented and a satisfactory current-limiting performance is demonstrated even if the arc voltage across the contacts is raised by the action of the arc shields.

While the current limiter thus far described is of the type in which the centrally mounted conductor turns thereby to close or open the contacts, the present invention is also applicable to a current limiter of another type. Figure 7 shows such current limiter to which the present invention is applicable. In Figure 7, numeral 21 designates a casing which is molded of an electrically insulating material. A movable contactor 22 is disposed inside the casing 21 in a manner to be turnable about a pivot pin 24 which is inserted through a hole 23. One end of the movable contactor 22 is provided with a contact 25, while the other end thereof is connected to an external conductor 31 through a flexible copper-stranded wire 30. A stationary contactor 26 is provided at its end with a contact 27 which falls within the locus of rotation of the contact 25 of the movable contactor 22. In the normal condition, the contact 25 is held in touch with the contact 27 under a required pressure by means of a spring 28. Parallel current paths close to each other are formed by the mutually opposing longitudinal parts of the stationary contactor 26 and the rotary contactor 22. An electric arc which is struck across the contacts 25 and 27 when they are separated from each other is stretched and cooled and then extinguished by arc extinguishing plates 32 in an arc extinguishing chamber 29 defined in the casing 21.

In the current limiter constructed as stated above, the movable contactor 22 has its longitudinal part located in opposition to the longitudinal part of the stationary contactor 26, so that the senses or polarities of currents flowing through the longitudinal parts of both the contactors are opposite to each other. Accordingly, when a current in excess of a predetermined value flows through this current limiter, the movable contactor 22 receives a counterclockwise turning force based on an electromagnetic repulsive force induced between it and the parallel stationary contactor 26, and the contacts 25 and 27 begin to separate against the spring 28, so that an electric arc is struck across the contacts.

The arc is cooled and split and then extinguished by the arc extinguishing plates 32 disposed in the arc extinguishing chamber 29.

With the above-stated current limiter of Figure 7, however the arc voltage across the contacts is limited to a certain value as described with reference to Figure 2, and the current limiting effect is not fully satisfactory.

Figure 8 shows a current limiter body 33 in another embodiment of the current limiter according to the present invention. Referring to Figure 8, arc shields 34a and 34b are disposed in a manner to respectively and individually surround the contact 25 of the movable contactor 22 and the contact 27 of the stationary contactor 26. A piece of an insulating material 35a is disposed on the conductor surface or bare charging part of the movable contactor 22 opposing to the stationary contactor 26, while a piece of the insulating material 35b is similarly disposed on the bare charging part of the stationary contactor 26. The method of forming the arc shields 34a and 34b is the same as stated in the embodiment of Figure 3.

In the present embodiment, same as in the embodiment of Figure 3, the arc voltage can be rapidly raised by the arc shields 34a and 34b so as to achieve an effective current-limiting function.

Figure 9 shows still another embodiment of the current limiter according to the present invention. As shown in the figure, this embodiment includes a pair of movable contactors 22a and 22b which are made of a conductor and which form parallel current paths. Both these contactors have contacts 25a and 25b on one end thereof, and have flexible copper-stranded wires 30a and 30b connected to the other ends thereof. These contactors are rotatable about pivot pins 24a and 24b, respectively. Symbols 34c and 34d indicate arc shields surrounding the respective contacts 25a and 25b, while symbols 35c and 35d indicate pieces of an insulating material covering the bare charging parts of the respective movable contactors 22a and 22b.

The method of forming the arc shields 34c and 34d is the same as stated in conjunction with the embodiment of Figure 3. In the present embodiment, same as in the embodiment of Figure 3, the arc voltage can be rapidly raised by the arc shields 34c and 34d so as to achieve an effective current-limiting function.

In case the embodiment shown in Figure 8 or 9 is applied to an electric circuit similar to the embodiment of Figure 3, the resistor may be connected in parallel as illustrated in Figure 5, whereby the arc voltage can be promptly turned over to the resistor after the occurrence of the arc across the contacts, and wear of the contacts can be prevented.

Claims:

1. A current limiter comprising a pair of contactor conductors (2, 6a, 6b) which have contacts (5a, 5b, 7a, 7b) fastened to their ends and which oppose in parallel with each other, at least one contact spring (8a, 8b) which urges a movable one of said conductors (2) to bring said contacts (5a, 5b, 7a, 7b) into engagement, and arc shields (10a, 10b, 11a, 11b) which are formed of a highly resistive material having a resistivity higher than that of said conductors (2, 6a, 6b) and which are disposed on said conductors (2, 6a, 6b) in a manner to surround said contacts (5a, 5b, 7a, 7b).

2. A current limiter according to claim 1, wherein one (2) of said pair of contactor conductors has the contacts at both its ends and has its central part supported turnably so as to form a rotary contactor (2); the other contactor conductor (6a or 6b) has the contacts (7a, 7b) fastened thereto which oppose said contacts (5a, 5b) turning with said rotary contactor (2), and forms a stationary contactor (6a or 6b); and an insulating material (12a, 12b, 13a, 13b) is disposed on at least one of opposing conductor surfaces of said rotary contactor (2) and said stationary contactor (6a or 6b).

3. A current limiter according to claim 2, wherein said pair of contactor conductors (2, 6a, 6b) are connected with each other by an external resistor (15).

4. A current limiter according to claim 1, wherein said pair of contactor conductors (22, 26) have the contacts (25, 27) at their one ends, one of said contactor conductors (22) has its other end supported rotatably so as to form a movable contactor (22), the other contactor

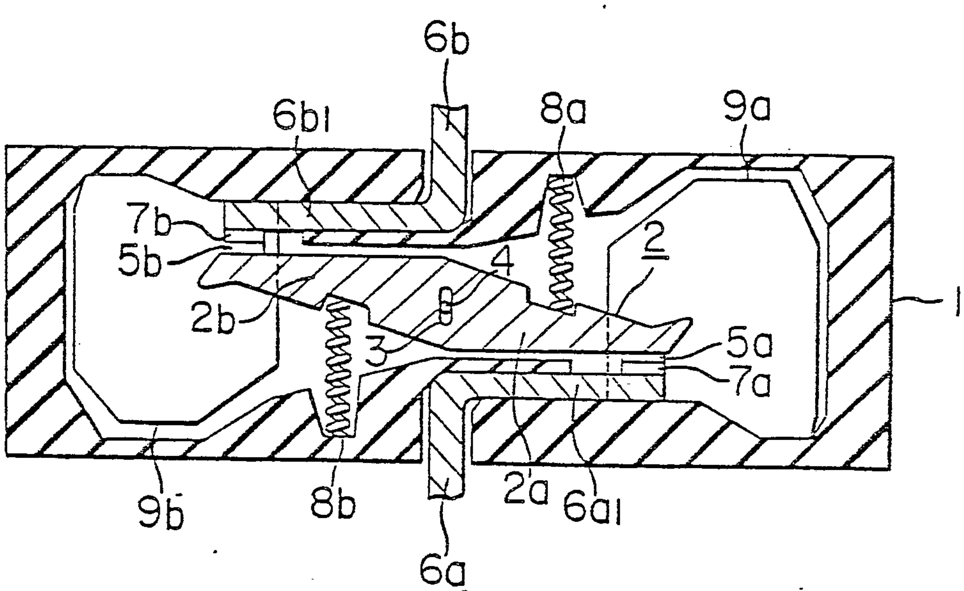
conductor (26) forming a stationary contactor (26), and an insulating material (35a, 35b) is disposed on at least one of opposing conductor surfaces of said movable contactor (22) and said stationary contactor (26).

5. A current limiter according to claim 4, wherein said pair of contactor conductors (22, 26) are connected with each other by an external resistor.

6. A current limiter according to claim 1, wherein each of said pair of contactor conductors (22a, 22b) has the contact (25a, 25b) at its one end and has its other end supported turnably, and an insulating material (35c, 35d) is disposed on at least one of opposing conductor surfaces of said contactor conductors (22a, 22b).

7. A current limiter according to claim 6, wherein said pair of contactor conductors (22a, 22b) are connected with each other by an external resistor.

FIG. 1a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9a
7b
5b
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4
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3
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7a
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6a1
6a

FIG. 1b

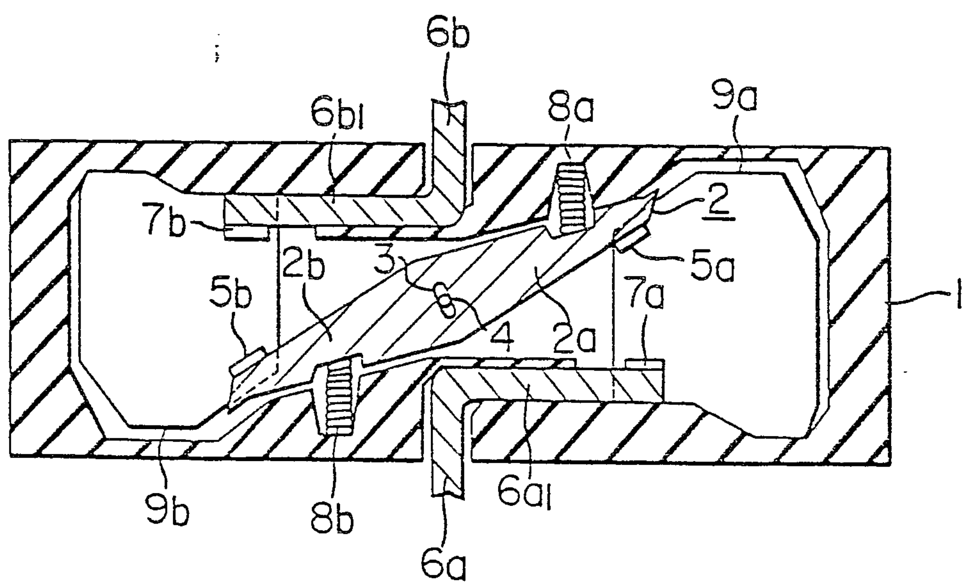
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FIG. 2

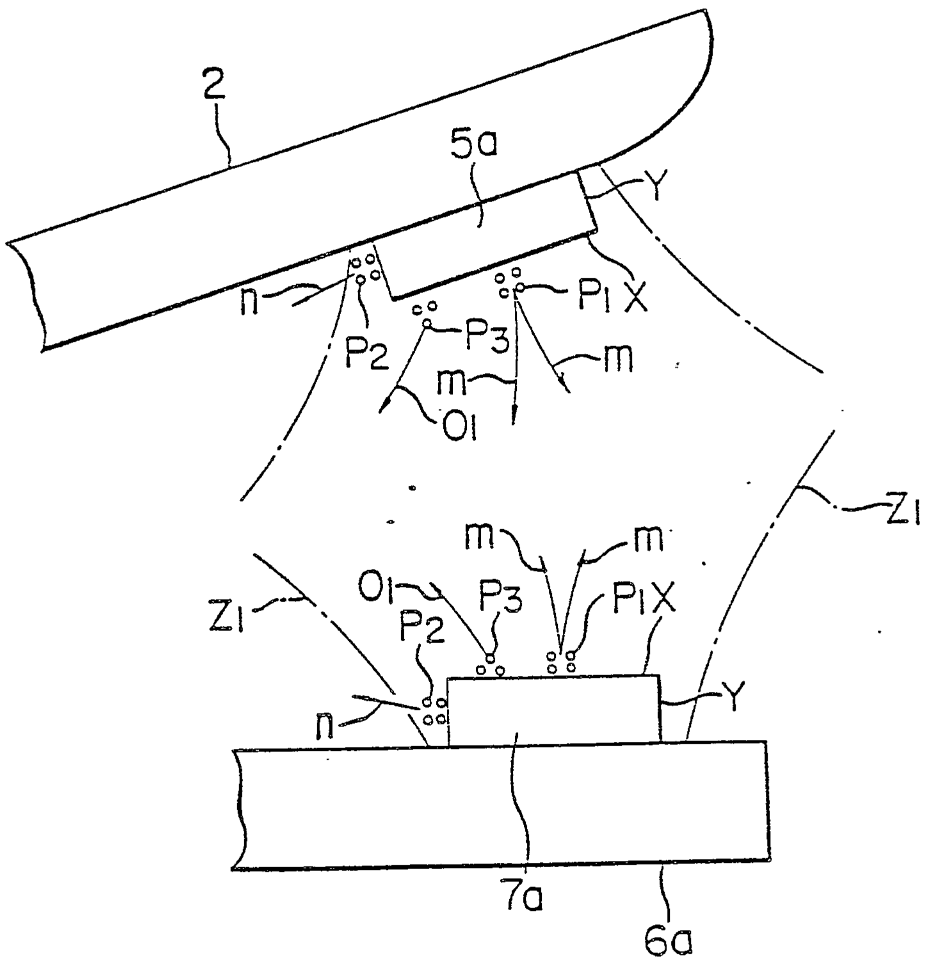
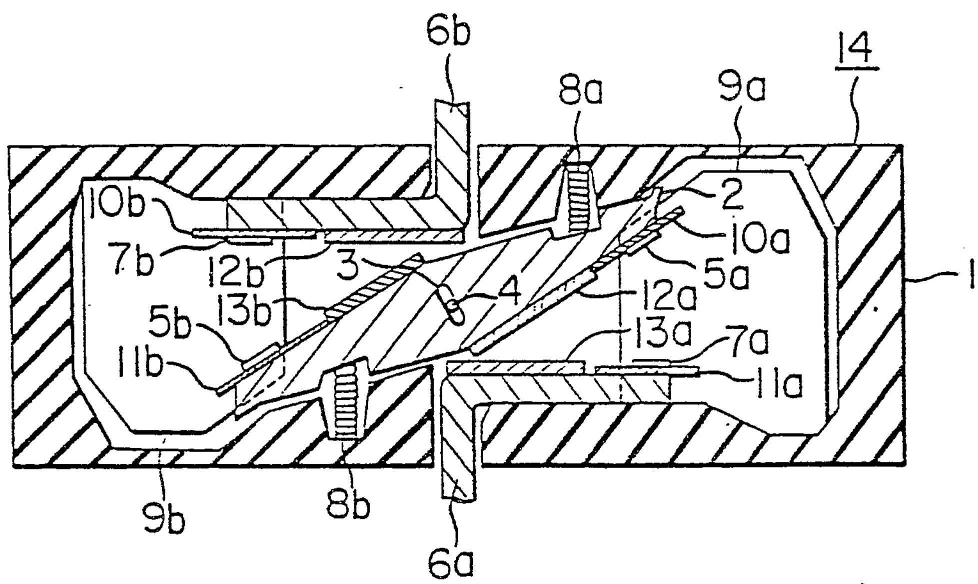


FIG. 3



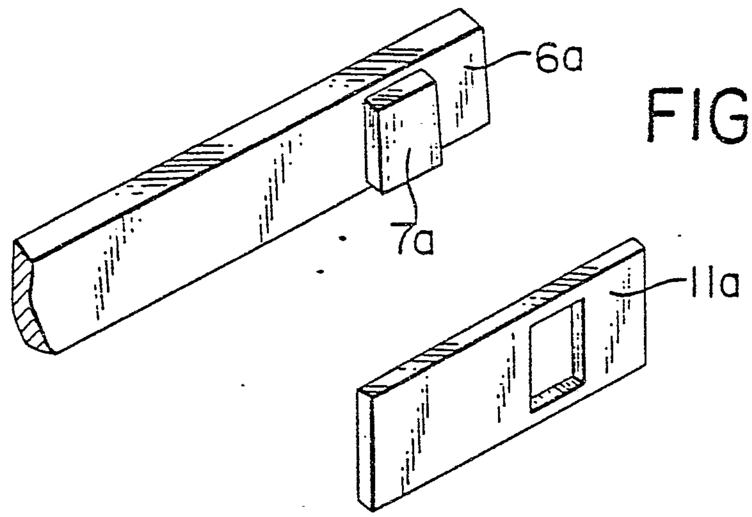
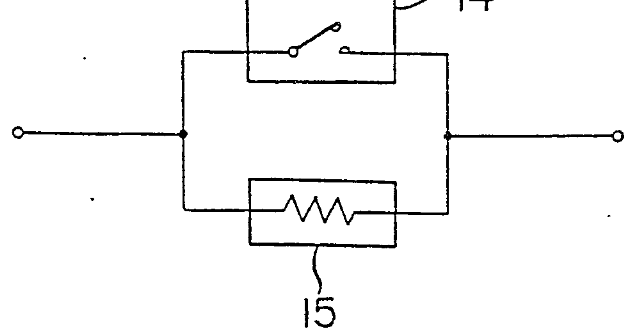
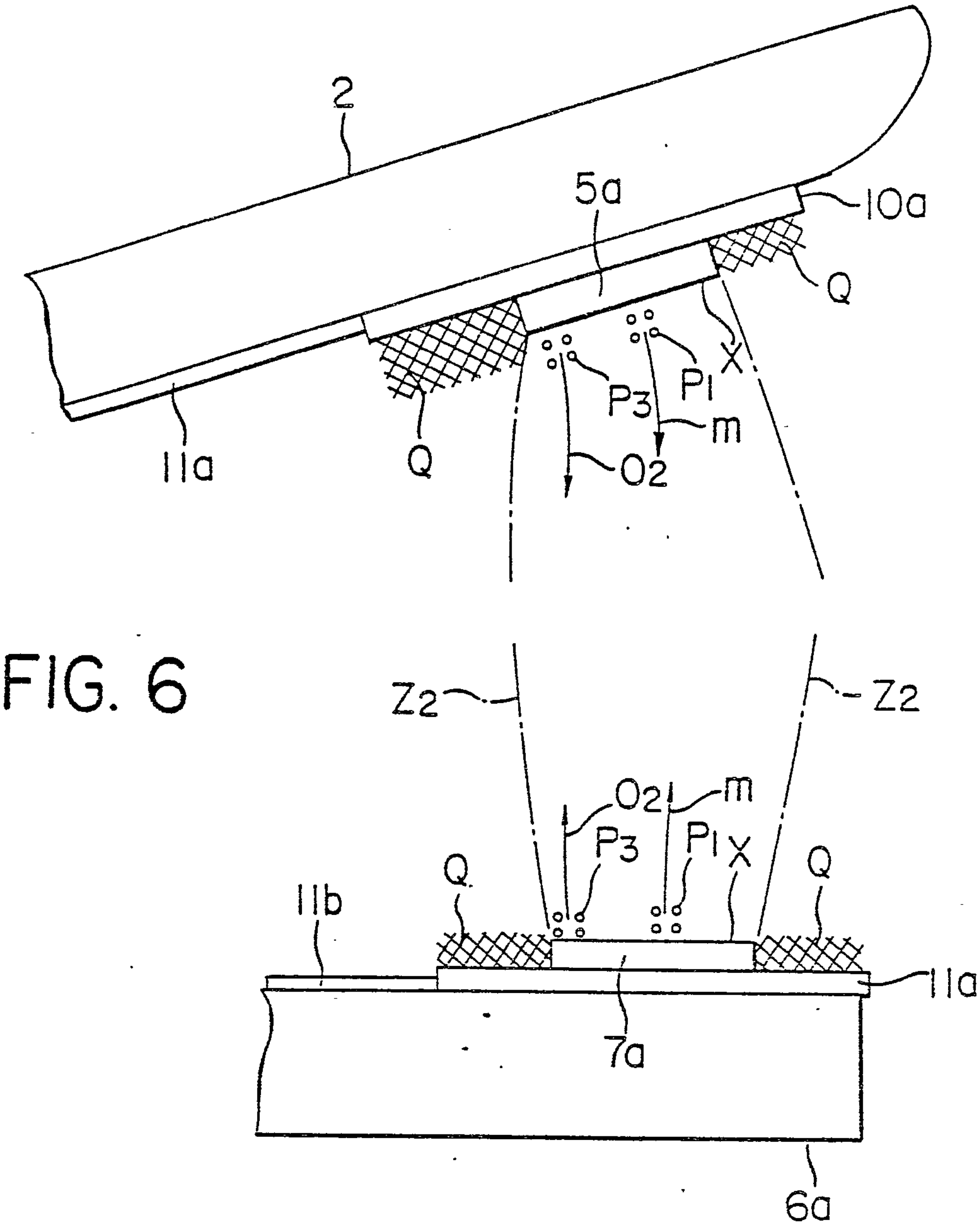


FIG. 4

FIG. 5

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P3
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11b
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7a
6a

FIG. 6

FIG. 7

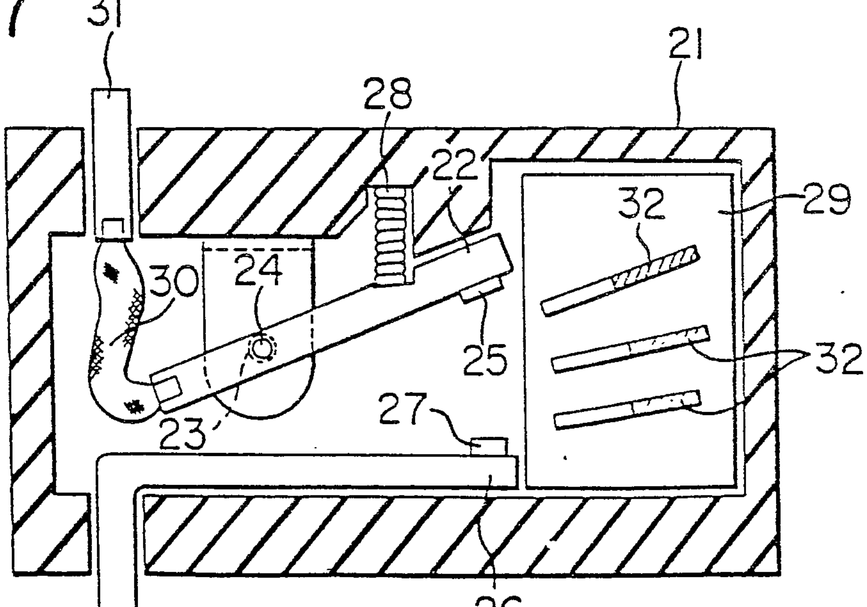
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FIG. 8

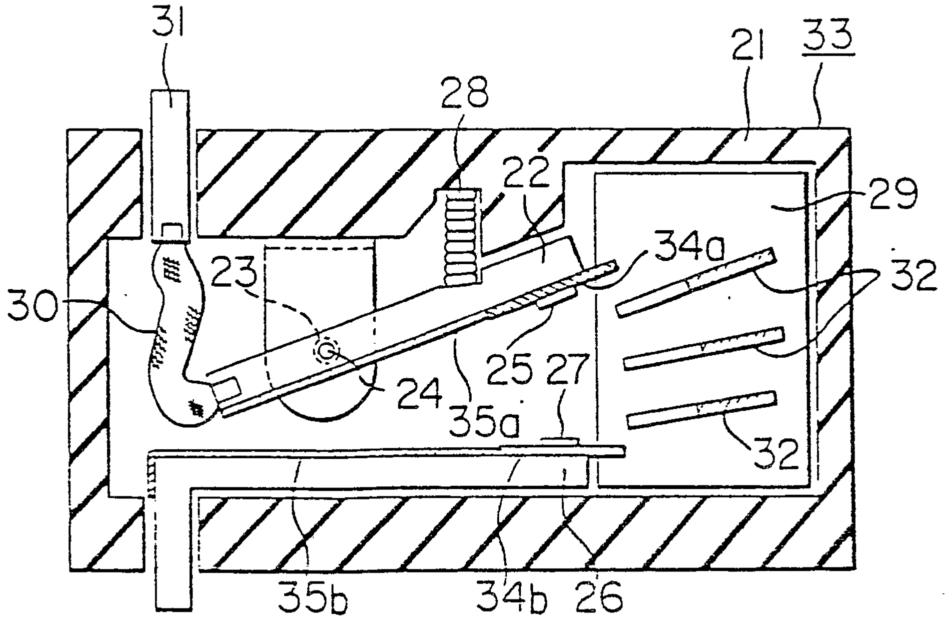
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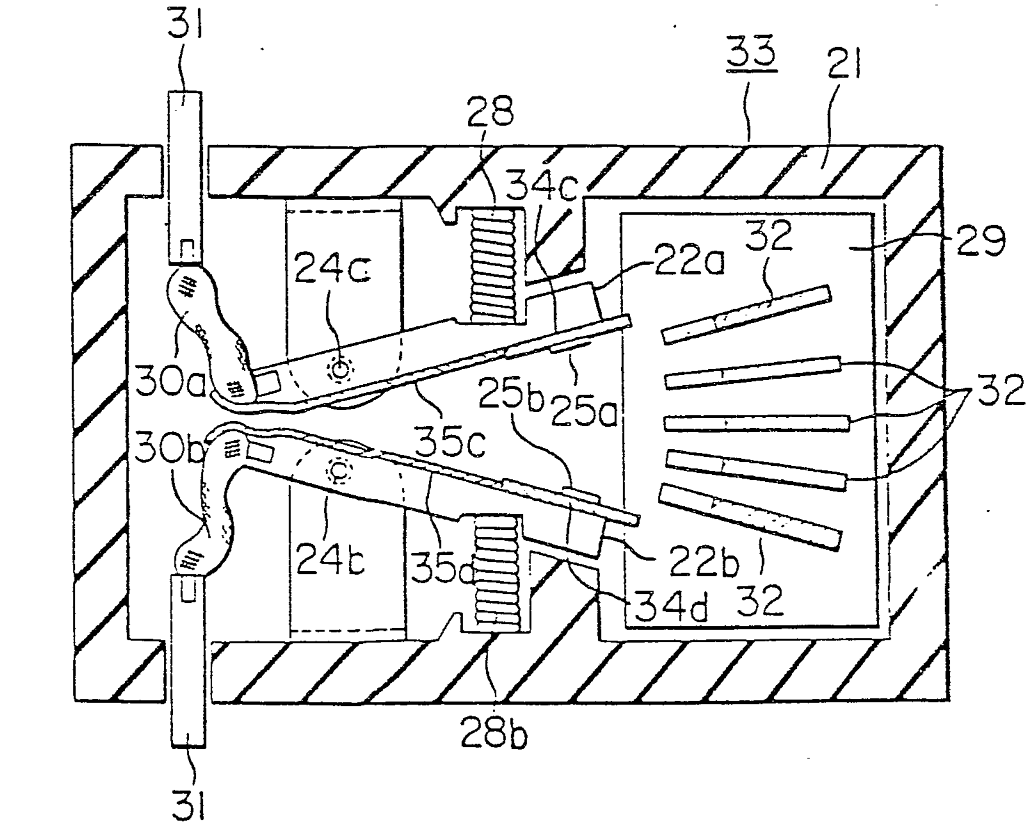
FIG. 9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