(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 233 323 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: 86115283.3

(51) Int. Cl.³: H 01 H 73/04

(22) Date of filing: 12.03.82

(30) Priority: 12.03.81 JP 35552/81 U
12.03.81 JP 35554/81 U
12.03.81 JP 35555/81 U
12.03.81 JP 35556/81 U
12.03.81 JP 35557/81 U

(43) Date of publication of application: 26.08.87 Bulletin 87/35

(84) Designated Contracting States: CH DE FR GB IT LI

(60) Publication number of the earlier application in accordance with Art. 76 EPC: 0 061 097

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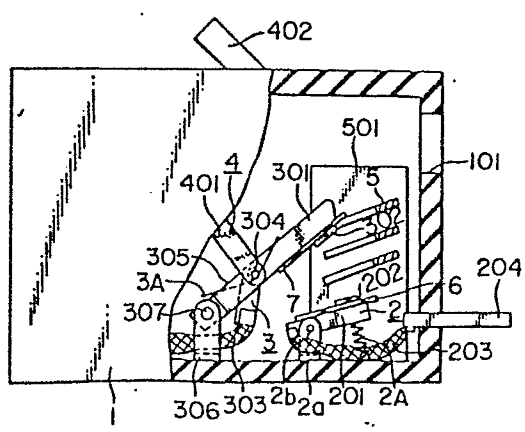
(54) **A circuit breaker.**

(57) The present invention relates to a circuit breaker wherein a pair of rigid conductors (201, 301) which are disposed therein and at least one of which has a movable portion that separates a pair of contacts (202, 302) by an electromagnetic force produced by an excess current flowing through the contacts (202, 302) adapted to come into and out of contact with and from each other, are provided with arc shields (6, 7) in a manner to surround the contacts (202, 302), thereby to bring forth the effects of increasing the arc voltage of an electric arc struck across the contacts (202, 302) and raising the separating speed of the contacts (202, 302).

FIG. 15(b)



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"A CIRCUIT BREAKER"

The present invention relates to an improved circuit breaker, more particularly to a circuit breaker which is so constructed as to increase the separating speed of its contacts and to effectively increase the arc voltage of an electric arc struck across the contacts to thus attain an enhanced current-limiting performance.

Prior circuit breakers have the disadvantage that an electric arc struck across contacts expands its feet (base) to the parts of rigid conductors near the contacts, so that metal particles of the contacts cannot be effectively injected into the arc. With the prior devices, it has been impossible to achieve the aforementioned effects of the circuit breaker according to the present invention.

The invention as claimed is intended to provide a circuit breaker wherein a pair of rigid conductors which are disposed therein and at least one of which has a movable portion that separates a pair of contacts under the action of the electromagnetic force of an excess current flowing through the contacts adapted to come into and out of contact with and from each other, are provided with arc shields of a high restistivity material in a manner to surround the contacts. Owing to the arc shields, the feet of an electric arc are prevented from spreading to the parts of the rigid conductors near the contacts, thereby to effectively inject the metal particles of the contacts into the arc and to raise the arc voltage of the electric arc, and the pressure of the arc space of the electric arc is increased, thereby to raise the separating speed of the contacts.

Preferred ways of carrying out the invention are described in detail below with reference to drawings, in which: -

Figure 1a is a sectional plan view of a conventional circuit breaker to which the present invention is applicable,

Figure 1b is a sectional side view taken along line b - b in Figure 1a,

Figure 2 is a model diagram showing the behaviour of an electric arc which is struck across the contacts of the circuit breaker in Figure 1a,

Figure 3a is a side view showing a known contactor,

Figure 3b is a plan view of the contactor in Figure 3a,

Figure 3c is a sectional front view taken along line c - c in Figure 3b,

Figure 4a is a side view showing in a model fashion the state of an electric arc in the case where the contactor in Figure 3a is used in a circuit breaker,

Figure 4b is a front view corresponding to Figure 4a,

Figure 5 is a model diagram showing the behaviour of the arc in Figure 4a,

Figure 6a is a sectional plan view showing an embodiment of a circuit breaker according to the present invention,

Figure 6b is a sectional side view taken along line b - b in Figure 6a and showing the state in which the contacts of the circuit greaker are disengaged,

Figure 7 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 6a are engaged,

Figure 8 is a model diagram showing the action of arc shields for use in the circuit breaker according to the present invention,

Figure 9 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 6a have started to separate,

Figure 10 is a perspective view of one contactor showing another embodiment of the arc shield for use in the circuit breaker of the present invention,

Figure 11 is a perspective view of the other contactor which corresponds to the contactor in Figure 10,

Figure 12a is a sectional plan view showing another embodiment of the circuit breaker according to the present invention,

Figure 12b is a sectional side view taken along line b - b in Figure 12a and showing the state in which the contacts of the circuit breaker are disengaged,

Figure 13 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 12a are engaged,

Figure 14 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 12a have started to separate,

Figure 15a is a sectional plan view showing still another embodiment of the circuit breaker according to the present invention,

Figure 15b is a sectional side view taken along line b - b in Figure 15a and showing the state in which the contacts of the circuit breaker are disengaged,

Figure 16 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 15a are engaged,

Figure 17 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 15a have started to separate,

Figure 18a is a sectional plan view showing a further embodiment of the circuit breaker according to the present invention,

Figure 18b is a sectional side view taken along line b - b in Figure 18a and showing the state in which the contacts of the circuit breaker are disengaged,

Figure 19 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 18a are engaged,

Figure 20 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 18a have started to separate,

Figure 21a is a sectional plan view showing a still further embodiment of the circuit breaker according to the present invention,

Figure 21b is a sectional side view taken along line b - b in Figure 21a and showing the state in which the contacts of the circuit breaker are disengaged,

Figure 22 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 21 are engaged, and

Figure 23 is a sectional side view showing the state in which the contacts of the circuit breaker in Figure 21a have started to separate.

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

Figures 1(a) and 1(b) illustrate a conventional circuit breaker. In Figures 1(a) and 1(b), assuming now that a movable contact 302 of a movable contactor 3 and a stationary contact 202 of a stationary contactor 2 are closed, current flows along the path from a stationary rigid conductor 201 to the stationary contact 202, to the movable contact 302 and to a movable rigid conductor 301.

When, under this state, a high current such as short-circuit current flows through the circuit, an operating mechanism 4 works to separate the movable contact 302 from the stationary contact 202. At this time, an electric arc A appears across the stationary contact 202 and the movable contact 302, and an arc voltage develops thereacross. The arc voltage rises as the distance of separation of the movable contact 302 from the stationary contact 202 increases. Simultaneously therewith, the arc A is drawn toward arc extinguishing plates 5 by a magnetic force and is stretched, so that the arc voltage rises still further. In this manner, the arc current reaches the current zero point to extinguish the arc A, so that the interruption is completed. During such interrupting operation, large quantities of energy are generated by the arc A across the movable contact 302 and the stationary contact 202 in a short time of several milliseconds. In consequence, the temperature of a gas within an enclosure 1 rises, and also the pressure thereof rises abruptly, but the gas at the high temperature and under the high pressure is emitted into the atmosphere through an exhaust port 101.

In case of the interruption, the circuit breaker and its internal constituent parts perform the operations as described above. Now, the operation of the stationary contact 202 and the movable contact 302 will be especially explained. In general, the arc resistance R is given by the following expression:

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

where ρ: arc resistivity ($\Omega\cdot$cm)
l: arc length (cm)
S: arc sectional area (cm^2)

In general, in a short arc A which has a high current of at least several kA and an arc length l of at most 50 mm, the arc space is occupied by the metal particles of rigid conductors with arc feet (bases) existing on their surfaces. Moreover, the emission of the metal particles occurs orthogonally to the conductor surfaces. At the emission, the emitted metal particles have a temperature close to the boiling point of the metal of the rigid conductors. Further, as soon as the metal particles are injected into the arc space, they are supplied with electrical energy to be raised in temperature and pressure and to bear a conductivity, and they flow away from the rigid conductors at high speed while expanding in a direction conforming with the pressure distribution of the arc space. The arc resistivity ρ and the arc sectional area S in the arc space are determined by the quantity of the metal particles produced and the direction of emission thereof. Accordingly, the arc voltage is determined by the behaviour of such metal particles. Next, the behaviour of such metal particles will be described with reference to Figure 2. Even when surfaces X are constructed of contact members, the behaviour of metal particles to be described below holds quite similarly.

Referring to Figure 2, a pair of rigid conductors 201 and 301 are ordinary conductors in the form of metallic cylinders confronting each other. The rigid conductor 201 is an anode, while the rigid conductor 301 is a cathode. The surfaces X of the respective conductors

201 and 301 are opposing surfaces which serve as contacting surfaces when the conductors 201 and 301 come into contact, and the surfaces Y of the respective conductors 201 and 301 are conductor surfaces which are electrically contacting surfaces other than the opposing surfaces X. A contour 2 indicated by a dot-and-dash line in the Figure 2 is the envelope of the arc A struck across the rigid conductors 201 and 301. Further, metal particles a and metal particles b are typically representative of the metal particles which are respectively emitted from the surfaces X and Y of the conductors 201 and 301 by vaporization, etc. The directions of emission of the metal particles a and b are the directions of flow lines indicated by arrows m and n, respectively.

Such metal particles a and b emitted from the conductors 201 and 301 have their temperature raised by the energy of the arc space from approximately 3,000°C, being the boiling point of the metal of the conductors, to a temperature at which the metal particles bear a conductivity, i.e., at least 8,000°C, or to a still higher temperature of approximately 20,000°C. In the process of the temperature rise, the metal particles take energy out of the arc space and thus lower the temperature of the arc space, resulting in an increased arc resistance R. The quantity of energy which the metal particles a and b take from the arc space increases with the extent of the temperature rise of the metal particles. In turn, the extent of the temperature rise is determined by the positions and emission paths in the arc space, of the metal particles a and b emitted from the conductors 201 and 301.

Further, the paths of the metal particles a and b emitted from the conductors 201 and 301 are determined depending upon the pressure distribution of the arc space.

The pressure of the arc space is determined by the mutual relationship between the pinch force of the current itself and the thermal expansion of the metal particles a and b. The pinch force is a quantity which is substantially determined by the density of the current. In other words, it is determined by the size of the foot of the arc A on the conductors 201 and 301. In general, the metal particles a and b may be considered to fly in the space determined by the pinch force while thermally expanding.

It is also known that, in case the feet of the arc A on the conductors 201 and 301 are not limited, the metal particles a fly unidirectionally from one conductor 301 against the other conductor 201 in the form of vapor jet. When, in this manner, the metal particles a fly unidirectionally from the one conductor 301 toward the other conductor 201, the metal particles a to be injected into the positive column of the arc A are supplied substantially from only the conductor on one side 301. While Figure 2 illustrates by way of example the case where the metal particles are flying strongly from the cathode against the anode, they sometimes fly in the opposite direction.

The above circumstances will now be described. In Figure 2, it is supposed that the metal particles fly unidirectionally from the conductor 301 toward the conductor 201 for any reason. The metal particles a starting from the surface X, the opposing surface of conductor 301, tend to fly orthogonally to the conductor surface, i.e. toward the positive column of the arc. At this time, the metal particle a having started from the surface X of one conductor 301 is injected into the positive column by the pressure caused by the pinch force. In contrast, the metal particle a having started from the surface X of the other conductor 201 is pushed by the particle stream in the positive column and ejected outside the surface X, and it is immediately forced out of the system without entering the positive column. In this manner, the movement of the metal particle a emitted from the conductor 201 and that of the metal particle a emitted from the conductor 301 are different as indicated by the flow lines of the arrows m and m' in Figure 2. As stated before, this is based on the difference between the pressures caused by the pinch forces on the conductor surfaces. Thus, the unidirectional blow from the conductor 301 heats the conductor 201 on the blown side and expands the foot (anode spot or cathode spot) of the arc on the surface of the conductor 201 from the front surface X thereof to the other surface thereof. In consequence, the current density on the conductor surface of the conductor 201 lowers, same as the pressure of the arc. Accordingly, the unidirectional blow from the conductor 3P1 is increasingly intensified. The discrepancy of the flight paths of the metal particles a emitted from the respective conductors 201 and 301 as has thus occurred, results in the discrepancy of the quantities of energy to be taken from the arc space. Accordingly, the metal particle a having started from the surface X of the conductor 301 can absorb energy from the positive column sufficiently, whereas the metal particle a having started from the surface X of the conductor 201 cannot absorb energy sufficiently and is ejected out of the system without cooling the arc A effectively. On the other hand, the metal particles b emitted from the surfaces Y of the respective conductors 201 and 301 do not deprive the arc A of sufficient heat, as indicated by arrows n in Figure 2. Moreover, they increase the arc sectional area S, resulting in a lowered resistance R of the arc A.

In this manner, in the presence of the blow from one conductor 301, the efficiency of the cooling of the positive column by the metal particles a is impaired. In addition, the metal particles b emitted from the non-opposing surfaces Y of both conductors 201 and 301 do not contribute to the cooling of the positive column at all, and they even lower the arc resistance R by increasing the arc sectional area S.

Accordingly, the presence of the unidirectional blow of the metal particles from one conductor to the other is disadvantageous for raising the arc voltage and renders it impossible to enhance the current-limiting performance at the tripping.

In general, the stationary rigid contactor and the movable rigid contactor used in the conventional circuit breaker are large in the surface area of the opposing surfaces, similarly to the rigid conductors of the model of Figure 2, so that they cannot limit the size of the foot of the struck arc, disadvantageously. Moreover, the contactors have the exposed surfaces such as side surfaces besides the opposing surfaces, so that as explained with reference to Figure 2, the position and size of the feet (anode spot and cathode spot) of the arc appearing on the surfaces of both conductors cannot be limited. In the mechanism explained with reference to Figure 2, accordingly, the unidirectional blow of the metal particles a from one contactor against the other contactor proceeds and therefore the arc sectional area increases, so that as stated above, the current-limiting performance at the tripping cannot be enhanced.

As an example of another contactor used in a prior circuit breaker, there has been one in which the part of a conductor surface adjacent to a contact is covered with an insulator 11 in order to prevent the fusion of a conductor to the area around the contact. Figures 3(a) to 3(c) show such contactor 2. In the example shown, the fore end part of the conductor is not covered with the insulator 11.

In a circuit breaker constructed as shown in Figures 4(a) and 4(b) and including a pair of rigid conductors of such construction, an electric arc A as illustrated in these Figures develops across the paired stationary contactor 2 and movable contactor 3. In the arc A, its feet or the positions of an anode spot and a cathode spot flare greatly toward the fore ends of the rigid conductors as appears from Figures 4(a) and (b), so there has been the disadvantage that the current-limiting performance at the tripping cannot be enhanced for the same reason as explained with reference to Figure 2. Further, regarding a case where, as shown in Figure 5, only one of a pair of contacts is provided with a coating which has a plate-shaped member 11 of an insulator covering the peripheral part of the contacting surface thereof, the state of the surface has been examined. In this example, metal particles the flow directions of which are confined are injected into an arc positive column portion from the surface X of a rigid conductor 301 which has the contact enclosed with the insulator 11. However, as regards metal particles from the surface X of a rigid conductor 201 which has the contact not coated with the insulator 11, the foot of an arc or the anode spot or cathode spot thereof spreads on the whole conductor surface without being limited, and further spreads to surfaces Y, i.e. the side surfaces of the contact, so that the current density decreases. It is accordingly the same as in Figure 2 that the pinch force weakens and that the metal particles run out of the arc. Therefore, even when the insulator is disposed in the vicinity of one conductor, the aspect of the arc positive column portion eventually becomes the phenomenon of the unidirectional blow of the metal particles. Accordingly, both conductors are subject to the same circumstances as in the case where the size of the foot of the arc is not limited, and the arc voltage does not show any especially great rise, so that the current-limiting performance is not enhanced.

As explained above, in order to raise the arc voltage, the metal particles having appeared in the feet of the arc need to be effectively injected into the positive column from both electrodes. The force which injects the metal particles into the positive column is the pressure based on the pinch force arising in the foot of the arc. Since the pinch force changes greatly depending upon the size of the foot of the arc on the contactor or upon the current density, it can be controlled. For example, in the conventional contactors, the area of the surface X of at least one contactor is large, and it does not limit the size of the foot of the arc to an effective degree. Even in such contactors employing no insulator, however, when the opposing surfaces X of both contactors are made sufficiently small, the density of current on the surfaces X rises to some extent, to increase the pinch forces, and the metal particles of the respective contactors are injected from both sides into the positive column to some extent, unlike the situations of the prior devices, whereby the arc voltage becomes higher than in the prior devices.

Merely with this measure, however, the spread of the foot of the arc to the other parts than the surfaces X or to the surfaces Y cannot be checked, and the current density on the surfaces X decreases by a component corresponding to the spread of the foot of the arc to the surfaces Y, so that the injection pressure of the metal particles lowers. In the case of the conventional contactors, accordingly, the effect of cooling the positive column by the metal particles is not obtained to maximum degree.

Further, the serious disadvantage of the conventional contactors is that, on account of the spread of the foot of the arc to the surface Y, the foot of the arc is liable to spread directly to the joint part between the contact and the conductor as is usually set on the surface Y, so the joint member of low fusing point is melted by the heat of the arc, the contact being prone to fall off.

Now, the invention provides a circuit breaker which has a high arc voltage and exhibits a good current-limiting performance at the tripping thereof and which is free from the risk of the falling-off of contacts.

The circuit breaker of this invention is characterized in that, except for a part of the electrically contacting surface of either contact of the circuit breaker, the part of a rigid conductor adjacent to the contact as projects to the surrounding space is concealed behind an arc shield (a plate-shaped pressure reflector or a covering such as taping and coating) which is made of a substance of a highly resistive material (called the "high resistivity material" hereinbelow) having a resistivity higher than that of a material forming the rigid conductor, thereby to forcibly inject metal particles into an arc space, and that the electrodes are separated at high speed by a high pressure established owing to the provision of the arc shield.

As the high resistivity material, there can be used, for example, an organic or inorganic insulator, or a high resistivity metal such as copper-nickel, copper-manganese, manganin, iron-carbon, iron-nickel and iron-chromium. It is also possible to use iron whose resistance increases abruptly in accordance with a temperature rise.

Figures 6(a) and 6(b) illustrate one embodiment of the circuit breaker according to this invention. In Figures 6(a) and 6(b), an enclosure 1 made of an insulator forms the outer frame of a switching device and is provided with an exhaust port 101. A first movable contactor 2 comprises a first movable rigid conductor 201 with the part intermediate its ends being turnably (pivotally) supported by a pivot pin 103 on a holder 102 that is fixed to the enclosure 1, as well as a first contact 202 which is mounted to one end part of the first conductor 201. A second movable contactor 3 comprises a second movable rigid conductor 301 which moves relative to the first movable rigid conductor 201 in order to close or open the circuit breaker, and a second contact 302 which is mounted on one end part of the second conductor 301 in a manner to confront the first contact 202. An conventional operating mechanism 4 operates the second movable contactor 3 relative to the first movable contactor 2 in order to close or open the circuit breaker (compare e.g. U.S. Patent 3,171,922). In the present embodiment, this mechanism comprises a supporter 402 which turnably (pivotally) supports the other end part of the second movable rigid conductor 301 by means of a pivot pin 401, a lower link 404 one end part of which is turnably mounted to the intermediate or central part of the second movable rigid conductor 301 by a pivot pin 403, an upper link 406 one end of which is turnably mounted to the other end part of the lower link 404 by a pivot pin 405, and an operating handle 407 which is turnably mounted to the other end part of the upper link 406 by a pivot pin (not shown). Arc extinguishing plates 5 which extinguish an electric arc struck when the second contact 302 is separated from the first contact 202, are supported by a pair of side plates 501 and 502. Arc shields 6 and 7, made of the aforementioned high resistivity material, are respectively mounted on the first and second movable rigid conductors 201 and 301 in a manner to have the first and second contacts 202 and 302 projecting therethrough and to oppose to the electric arc. A spring 8 being interposed between the enclosure 1 and the first movable rigid conductor 201 urges the first contact 202 against the second contact 302. A connection terminal 9 is connected to the first movable rigid conductor 201 through a flexible conductor 10, and also to an external conductor (not shown).

Now, when the operating handle 407 is turned clockwise according to Figure 6(b), the linkage composed of the upper and lower links 406 and 404 operates to engage the first and second contacts 202 and 302 as illustrated in Figure 7. Accordingly, current flows from a power supply side onto a load side from the connection terminal 9, to flexible conductor 10, to first movable rigid conductor 201, to first contact 202, to second contact 302 and to second movable rigid conductor 301. When, under this state, a high current, such as a short-circuit current, flows through the circuit, the second contact 302 is separated from the first contact 202 by an electromagnetic repulsive force based on current concentration in the contacting points of the contacts 202 and 302. At this time, an electric arc develops across the first contact 202 and the second contact 302. As illustrated in Figure 8, metal particles are reflected in the arc by the arc shields 6 and 7 to render the pressure of the arc space high, with the result that the separation of the contacts is promoted and that the arc is effectively cooled.

Figure 8 is an explanatory model diagram of the behaviour of the metal particles in the circuit breaker of Figures 6(a) and 6(b). Even in a case where surfaces X are formed of contact members, the behaviour of the metal particles does not differ from the ensuing explanation at all. In Figure 8, a pair of rigid conductors 201 and 301 are constructed in the same shape as in Figure 2, and the arc shields 6 and 7 are respectively mounted on the conductors 201 and 301 in a manner to expose the surfaces X, i.e. the mutually confronting surfaces of the conductors 201 and 301, and to oppose to the arc A. Although pressure values in spaces Q, Q cannot exceed the pressure value of the space of the arc A itself, much higher values are exhibited at least in comparison with the values in the case where the arc shields 6 and 7 are not provided. Accordingly, the peripheral spaces Q, Q in which the relatively high pressures are caused by the arc shields 6 and 7, afford forces suppressing the spread of the space of the arc A and "narrow" (confine) the arc A within a small space. This results in narrowing and confining into the arc space the flow lines m, m', o and o' of the metal particles a, c, etc. emitted from the opposing surfaces X. Therefore, the metal particles a and c emitted from the surfaces X are effectively injected into the arc space. As a result, the metal particles a and c effectively injected in large quantities deprive the arc space of large quantities of energy beyond comparison with those in the prior device, to therefore cool the arc space remarkably. Accordingly, the resistivity ρ or the arc resistance R is raised remarkably, and the arc voltage is raised very greatly.

Further, when the arc shields 6 and 7 are installed closely around the contacting surfaces of the first contact 202 and the second contact 302 as shown by way of example in Figures 6(a) and 6(b), i.e. the opposing surfaces X according to Figure 8, the arc A is prevented from moving to the conductor surfaces Y, so that the size of the feet of the arc A is also limited. For this reason, the generation of the metal particles a and c can be concentrated on the surfaces X, and also the arc sectional area S can be reduced, whereby the effective injection of the metal particles a and c into the arc space can be further promoted. Accordingly, the cooling of the arc space, the rise of the arc resistivity ρ and the rise of the arc resistance R are further promoted, and the arc voltage can be raised further.

The first movable rigid conductor 201 is turnably held on the holder 102 by the pivot pin 103, so that when the arc A has developed immediately after the separation of the first and second contacts 202 and 302, this first conductor 201 is separated from the second movable rigid conductor 301 at very high speed by the forces produced by the pressures of the spaces Q rendered very high owing to the effect of the arc shields 6 and 7. This state immediately after the separation is shown in Figure 9. More specifically, before the open state shown in Figure 6(b) is established, the second movable rigid conductor 301 can have only a comparatively low separating speed on account of the inertia of the operating mechanism 4, whereas the first movable rigid conductor 201 has the very high separating speed owing to the pressure of the space Q. Therefore, the rise of the arc voltage immediately after the separation of the first and second contacts 202 and 302 becomes abrupt, and the peak value of the current to flow through the circuit is suppressed.

For the arc extinguishing plates 5, a magnetic material may be employed so as to attract the arc A and to consequently raise the arc voltage; alternatively, a nonmagnetic material may be employed so as to split the arc A and to consequently raise the arc voltage. With the magnetic material, the arc A is favorably cooled, but a temperature rise attributed to eddy current due to the magnetic material poses a problem in a circuit breaker of a high rated current. With the non-magnetic material, this problem is avoided.

Figures 10 and 11 are perspective views showing another embodiment of the arc shields, which can be applied also to other embodiments to be described later. Referring to Figures 10 and 11, grooves or arc runways 601 and 701 are respectively provided in the arc shields 6 and 7 to extend from the first and second contacts 202 and 302 toward the arc extinguishing plates 5, so as to expose the first and second movable rigid conductors 201 and 301. Owing to the provision of the grooves 601 and 701, the arc A runs toward the arc extinguishing plates 5 within these grooves, to become effectively extinguished in direct contact with the arc extinguishing plates 5.

This described embodiment of the circuit breaker according to the invention is adapted to separate the first movable rigid conductor 201 at high speed by mounting the arc shields 6 and 7, so that the arc voltage can be remarkably raised far beyond the limit thereof in the prior circuit breaker, and so that a high current-limiting performance can be attained.

Figures 12(a) and 12(b) show another embodiment of the circuit breaker according to this invention, in which an enclosure 1 forming the outer frame of a switching device is made of an insulator and is provided with an exhaust port 101.

A first contactor 2 is constructed of a first rigid conductor 201 which is turnably supported by a pivot pin 2b on a holder 2a that is fixed to the enclosure 1, and a first contact 202 which is mounted on one end part of the first rigid conductor 201. The first rigid conductor 201 is connected to a connection terminal 204 through a flexible conductor 203. A second contactor 3 moves relative to the first contactor 2 in order to close or open the circuit breaker, and it comprises a second rigid conductor 301 which is operated relative to the first rigid conductor 201 so as to close or open the circuit breaker, and a second contact 302 which is mounted on one end part of the second rigid conductor 301 in a manner to confront the first contact 202. The second rigid conductor 301 is connected to an external conductor (not shown) through a flexible conductor 303, and the other end part thereof is turnably held by a pivot pin 305 on a holder 304 that is fixed to the enclosure 1. A spring 2A being interposed between the first rigid conductor 201 and the enclosure 1 urges the first contact 202 against the second contact 302. An operating mechanism 4 for operating the second contactor 3 so as to close or open the circuit breaker, is formed so that one end part of a lower link 401 constituting a linkage is turnably coupled to the second rigid conductor 301 by a pivot pin 402, that one end part of an upper link 403 is turnably coupled to the other end part of the lower link 401 by a pivot pin 404, and that an cperating handle 405 is turnably coupled to the other end part of the upper link 403 by a pivot pin (not shown). Arc extinguishing plates 5 extinguish an electric arc struck when the second contact 302 is separated from the first contact 202, and they are supported by a pair of side plates 501 and 502. Arc shields 6 and 7 made of the aforementioned high resistivity material are respectively mounted on the first and second rigid conductors 201 and 301 in a manner to have the first and second contacts 202 and 302 projecting therethrough and to oppose to the electric arc.

Next, the operation of this embodiment will be described. When the operating handle 405 is turned clockwise, the first and second contacts 202 und 302 are engaged as illustrated in Figure 13. When in this state a high current such as short-circuit current flows, the first and second rigid conductors 201 and 301 are electromagnetically repelled on account of parallel currents which flow through these rigid conductors in senses opposite to each other, and the first rigid conductor 201 is separated as shown in Figure 14, so that the electric arc A develops across the first and second contacts 202 and 302. Subsequently, the operating mechanism 4 works to completely separate the second rigid conductor 301. In the arc A in this case, as illustrated in Figure 8, metal particles are reflected by the arc shields 6 and 7 to render the pressure of the arc space high, with the result that the arc is effectively cooled and extinguished.

In the embodiment as described above, the first rigid conductor 201 is turnably held on the holder 2a by the pivot pin 2b. Therefore, when the high current, such as a short-circuit current flows, the first and second rigid conductors 201 and 202 are electromagnetically repelled by the currents flowing therethrough, without waiting for the operation of the operating mechanism 4, so that the first rigid conductor 201 is separated to generate the arc A. Upon the generation of the arc A, the pressure of the space Q between the arc shields 6 and 7 becomes very high, and hence, the first and second rigid conductors 201 and 301 can be separated at very high speed by the effect of the arc shields 6 and 7 in addition to the electromagnetic repellent force, so that the arc voltage starts rising very quickly and rises very greatly. Accordingly, the peak value of the current to flow through the circuit can be made very small, the arc voltage can be made remarkably higher than in the prior circuit breaker, and a very high current-limiting performance can be attained.

Figures 15(a) and 15(b) show still another embodiment, in which an enclosure 1 made of an insulator forms the outer frame of a switching device and is provided with an exhaust port 101. A first contactor 2 is constructed of a first rigid conductor 201, and a first contact 202 which is mounted on one end part of the first rigid conductor 201, the other end part of which is turnably supported by a pivot pin 2b on a holder 2a fixed to the enclosure 1. The first rigid conductor 201 is connected to a connection terminal 204 through a flexible conductor 203. A second contactor 3 being movable relative to the first contactor 2 in order to close or open the circuit breaker, is constructed of a second rigid conductor 301 which is operated relative to the first rigid conductor 201 so as to close or open the circuit breaker, and a second contact 302 which is mounted on one end part of the second rigid conductor 301 in a manner to confront the first contact 202. The second rigid conductor 301 is connected to an external conductor (not shown) through a flexible conductor 303, and the intermediate part thereof is turnably supported on one end part of a movable frame member 305 by a pivot pin 304. The other end part of the movable frame member 305 is turnably supported on a supporter 306 by a pivot pin 307. A spring 2A is interposed between the first rigid conductor 201 and the enclosure 1, and a torsion spring 3A is applied to the pivot pin 304 and has its respective end parts held in engagement with the second rigid conductor 301 and the movable frame member 305. These springs bias the first and second contacts 202 and 302, respectively. An operating mechanism 4 for operating the second contactor 3 so as to close or open the circuit breaker, is formed so that one end part of a lower link 401 constituting a linkage is turnably coupled to the pivot pin 304 and that also an operating handle 402 is turnably coupled to the linkage. Arc extinguishing plates 5 extinguish an electric arc struck when the second contact 302 is separated from the first contact 202, and they are supported by a pair of side plates 501 and 502. Arc shields 6 and 7 made of the aforementioned high resistivity material are respectively mounted on the first and second rigid conductors 201 and 301 in a manner to have the first and second contacts 202 and 302 projecting therethrough and to oppose to the electric arc A.

When the operating handle 402 is turned clockwise, the first and second contacts 202 and 302 are engaged as illustrated in Figure 16. When a high current, such as a short-circuit current flows under these conditions, the first and second rigid conductors 201 and 301 are electromagnetically repelled on account of parallel currents flowing in senses opposite to each other through these rigid conductors, and the first and second rigid conductors 201 and 301 are both separated, so that the electric arc A develops across the first and second contacts 202 and 302 as illustrated in

Figure 17. Thereafter, the operating mechanism 4 works to completely separate the second rigid conductor 301. In the arc A in this case, as illustrated in Figure 8, metal particles are reflected by the arc shields 6 and 7 to render the pressure of the arc space high, with the result that the arc is effectively cooled and extinguished.

In the embodiment as described above, the other end part of the second rigid conductor 301 is turnably supported on the movable frame member 305 by the pivot pin 304, the other end part of the first rigid conductor 201 is turnably supported on the supporter 2a by the pivot pin 2b, and the currents flowing through the first and second rigid conductors 201 and 301 are in parallel and opposite in sense to each other. Therefore, when the high current, such as short-circuit current flows, the first and second rigid conductors 201 and 301 are electromagnetically repelled by the currents flowing therethrough, without waiting for the operation of the operating mechanism 4. The electromagnetic repellence separates both the first and second rigid conductors 201 and 301, to generate the arc A. Upon the generation of the arc A, the rigid conductors can be separated at very high speed by the pressure rise of the space Q between the arc shields 6 and 7, in addition to the electromagnetic repellent force. Accordingly, the arc voltage starts rising very quickly. Since both the first and second rigid conductors 201 and 301 separate, the arc length stretches, and this raises the arc voltage very greatly conjointly with the effect of the arc shields 6 and 7, so that the peak value of the current to flow through the circuit can be made very small.

In a circuit breaker for alternating current, the polarity of the current on a contact during arcing is not decided; moreover, the polarity on the same contact changes even during arcing. In this regard, the circuit breaker of the present embodiment can prevent the polarity effect on the current-limiting performance from becoming different in dependence on whether the polarity on the contact to be separated by the electromagnetic repellence is a cathode or an anode, and it can stabilize the current-limiting performance. That is, such beneficial result is achieved by the measure that both the first rigid conductor 201 and the second rigid conductor 301 on which the first contact 202 and the second contact 302 are respectively mounted, are formed of the turnable electromagnetic repulsion type.

Figure 18(a) and 18(b) show yet another embodiment, wherein an enclosure 1 made of an insulator forms the outer frame of a switching device and is provided with an exhaust port 101. A stationary contactor 2 is constructed of a stationary rigid conductor 201 which is fixed to the enclosure 1, and a stationary-side contact 202 which is mounted on one end part of the stationary rigid conductor 201. A movable contactor 3 being movable relative to the stationary contactor 2 in order to close or open the circuit breaker, is formed of a movable rigid conductor 301 which is operated relative to the stationary contactor 2 so as to close or open the circuit breaker, and a movable-side contact 302 which is mounted on one end part of the movable rigid conductor 301 in a manner to confront the stationary-side contact 202. The movable rigid conductor 301 is connected to an external conductor (not shown) through a flexible conductor 303, and the intermediate part thereof is turnably supported on one end part of a movable frame member 305 by a pivot pin 304. A cross bar 306 is penetratingly inserted in the other end part of the movable frame member 305 in a direction perpendicular to the plane of the drawing, and it turnably supports the movable frame member 305 in each phase. An operating mechanism 4 for operating the movable contactor 3 so as to close or open the circuit breaker, is constructed of a lower link 401 one end part of which is turnably mounted on the intermediate part of the movable rigid conductor 301 by the pivot pin 304, an upper link 403 one end part of which is turnably mounted on the other end part of the lower link 401 by a pivot pin 402, an operating handle 404 which is turnably mounted on the other end part of the upper link 403 by a pivot pin (not shown), and a torsion spring 405 which is applied to the pivot pin 304 and has its respective end parts held in engagement with the movable rigid conductor 301 and the movable frame member 305. Arc extinguishing plates 5 extinguish an electric arc struck when the movable contact 302 is separated from the stationary contact 202, and they are held by a pair of side plates 501 and 502. Arc shields 6 and 7 are made of the afore-mentioned high resistivity material, and are respectively mounted on the stationary rigid conductor 201 and the movable rigid conductor 301 in a manner to project the stationary contact 202 and the movable contact 302 and to oppose to the electric arc A.

When the operating handle 404 is turned clockwise, the movable contact 302 and the stationary contact 202 are engaged as illustrated in Figure 19. In this state, current flows from a power supply side to a load side via the stationary rigid conductor 201, the stationary contact 202, the movable contact 302 and the movable rigid conductor 301. In this state, the directions of currents flowing through the movable rigid conductor 301 and the stationary rigid conductor 201 are the same. Therefore, even when a comparatively great current flows, the repulsion between the movable rigid conductor 301 and the stationary rigid conductor 201 as caused by the currents flowing therethrough does not take place. That is, even when a comparatively great instantaneous current flows, the repulsion between the stationary-side contact 202 and the movable-side contact 302 does not occur unnecessarily, so that the stationary contact 202 and the movable contact 302 experience little wear and can be prevented from fusing and depositing. Now, when a high current, such as short-circuit current, flows through the circuit, the operating mechanism 4 works to separate the movable contact 302 from the stationary contact 202. At this time, the electric arc A develops across contacts 202 and 302. This state is illustrated in Figure 20. In the arc A, as illustrated in Figure 8, metal particles are reflected by the arc shields 6 and 7 to render the pressure of the arc space high, with the result that the arc is effectively cooled and extinguished.

In the embodiment as described above, the movable rigid conductor 301 is turnably held on the movable frame member 305 by the pivot pin 304; further, the arc shields 6 and 7 are provided. Accordingly, although the operating mechanism 4 affords a low separating speed of the movable rigid conductor 201 on account of its inertia, the pressure of the space Q between the arc shields 6 and 7 becomes very high and the movable rigid conductor 201 is therefore separated at very high speed without waiting for the drive of the operating mechanism 4. In consequence, the rise of the arc voltage immediately after the separation is rapid, and this suppresses the peak value of the current to flow through the circuit, conjointly with the effect of narrowing the arc A by the arc shields 6 and 7, so that a high current-limiting effect can be attained.

Figures 21(a) and 21(b) show a further embodiment, wherein an enclosure 1 made of an insulator forms the outer frame of a switching device and is provided with an exhaust port 101. A first contactor 2 is constructed of a first rigid conductor 201 which is turnably supported by a pivot pin 2b on a holder 2a fixed to the enclosure 1, and a first contact 202 which is mounted on one end part of the first rigid conductor 201. The first rigid conductor 201 is connected to a connection terminal 204 through a flexible conductor 203. A second contactor 3 being movable relative to the first contactor 2 in order to close or open the circuit breaker, is constructed of a second rigid conductor 301 which is operated relative to the first rigid conductor 201 so as to close or open the circuit breaker, and a second contact 302 which is mounted on one end part of the second rigid conductor 301 in a manner to confront the first contact 202. The second rigid conductor 301 is connected to an external conductor (not shown) through a flexible conductor 303, and the intermediate part thereof is turnably held on one end part of a movable frame member 304 by a pivot pin 305. A cross bar 306 is mounted on the other end part of the movable frame member 304 in a direction perpendicular to the plane of the drawing, and acts to move the movable frame member simultaneously in each phase. A torsion spring

307 is applied to the pivot pin 305 and has its respective end parts held in engagement with the second rigid conductor 301 and the movable frame member 304. A spring 2A being interposed between the first rigid conductor 201 and the enclosure 1 urges the first contact 202 against the second contact 302. An operating mechanism 4 operates the second contactor 3 in order to close or open the circuit breaker, and is formed so that one end part of a lower link 401 constituting a linkage is turnably coupled to the second rigid conductor 301 by the pivot pin 305, that one end part of an upper link 402 is turnably coupled to the other end part of the lower link 401 by a pivot pin 403, and that an operating handle 414 is turnably coupled to the other end part of the upper link 402 by a pivot pin (not shown). Arc extinguishing plates 5 to extinguish an electric arc struck when the second contact 302 is separated from the first contact 202 are supported by a pair of side plates 501 and 502. Arc shields 6 and 7 made of the aforementioned high resistivity material are respectively mounted on the first and second rigid conductors 201 and 302 in a manner to have the first and second contacts 202 and 302 passing therethrough and to oppose to the electric arc. When the operating handle 404 is turned clockwise, the first and second contacts 202 and 302 are engaged as illustrated in Figure 22. When a high current, such as a short-circuit current flows in this state, the first and second rigid conductors 201 and 301 are not repelled electromagnetically because parallel currents flow in an identical sense through these rigid conductors, and the first rigid conductor 201 is separated as illustrated in Figure 23, so that the electric arc A develops across the first and second contacts 202 and 302. Subsequently, the operating

mechanism 4 works to completely separate the second rigid conductor 301. In the arc A in this case, as illustrated in Figure 8, metal particles are reflected by the arc shields 6 and 7 to render the pressure of the arc space high, with the result that the arc is effectively cooled and extinguished.

In this embodiment, the first rigid conductor 201 is turnably held on the movable frame member 304 by the pivot pin 305; further the arc shields 6 and 7 are provided. Accordingly, although the operating mechanism 4 affords a low separating speed of the movable rigid conductor 201 on account of its inertia, the pressure of the space Q between the arc shields 6 and 7 becomes very high and the movable rigid conductor 201 is therefore separated at very high speed without waiting for the drive of the operating mechanism 4. In consequence, the rise of the arc voltage immediately after the separation is rapid, and this suppresses the peak value of the current to flow through the circuit, conjointly with the effect of narrowing the arc A by the arc shields 6 and 7, so that a high current-limiting effect can be attained. Further, even when a comparatively great instantaneous current flows, the repulsion between the first and second contacts 202 and 302 does not take plase unnecessarily.

In a circuit breaker for alternating current, the polarity of the current on a contact during arcing is not decided, and moreover, the polarity on the same contact changes even during arcing. In this regard, the circuit breaker of the present embodiment can prevent the polarity effect on the current-limiting performance from becoming different depending upon whether the polarity on the contact to be separated by the electromagnetic repellence is a cathode or an anode, and it can stabilize the current-limiting performance. That is, such beneficial result is achieved by the measure that both the first rigid conductor 201 and the second rigid conductor 301 on which the first contact 202 and the second contact 302 are respectively mounted are formed of the turnable electromagnetic repulsion type.

Patent Claims

1. Circuit breaker comprising an operating mechanism to close or open an electric circuit by engaging or disengaging a pair of contacts, said pair of contacts being disposed on current conducting contactor arms of which at least one of these contactor arms is pivotally supported in order to be able to move from and towards the opposite contact,
characterized in, that
arc shields (6, 7) are disposed on said contactor arms (2, 3) in a way as to surround the respective contacts (202, 302),
the first contactor arm (3), is pivotally mounted on the enclosure (1) and is additionally provided with a further spring loaded pivot in its intermediate part realizing a contactor arm in form of a toggle element connected with the operation mechanism (4).
the second contactor arm (2) is pivotally supported on the enclosure (1) and provided with a spring (2 A)

forcing the contactor arm (201) in direction towards the first contactor arm (3), and
these contactor arms (2, 3) are arranged to each other in parallel and symmetric way, so that a current loop is formed in the closed state.

2. Circuit breaker according to claim 1,
c h a r a c t e r i z e d   i n ,   t h a t
the first contactor arm (3) comprises a first conductor (301), which is pivotally mounted on said contactor arm (3) at the intermediate part thereof and is furthermore connected to an external terminal via a flexible conductor (303), and
the conductor (201) of the second contactor arm (2) is connected to an external terminal (204) via a flexible conductor (203).

3. Circuit breaker according to claim 1 and 2,
c h a r a c t e r i z e d   i n ,   t h a t
the arc shields (6, 7) are made of high resistivity material and are disposed in a manner to fully surround the peripheries of the first and second contacts (202, 302) and to conceal parts of the first and second contactor arms (2, 3) adjacent to the contacts (202, 302), respectively.

4. Circuit breaker according to claim 1,
c h a r a c t e r i z e d   i n ,   t h a t
at least one of the arc shields (6, 7) is provided with a groove or an arc run way (601, 701) extending from the

respective contact (202, 302) towards the arc extinguishing plates (5) and exposing the respective conductors (201, 301).

5. Circuit breaker according to claim 3, characterized in, that the high resistivity material of the arc shields (6, 7) is an organic or inorganic isolator.

6. Circuit breaker according to claim 3 and 5, characterized in, that the high-resistivity material of the arc shields (6, 7) is a high resistivity metal such as copper-nickel, copper-manganese, manganin, iron-carbon, iron-nickel, iron-cromium and iron.

FIG. 1(a)

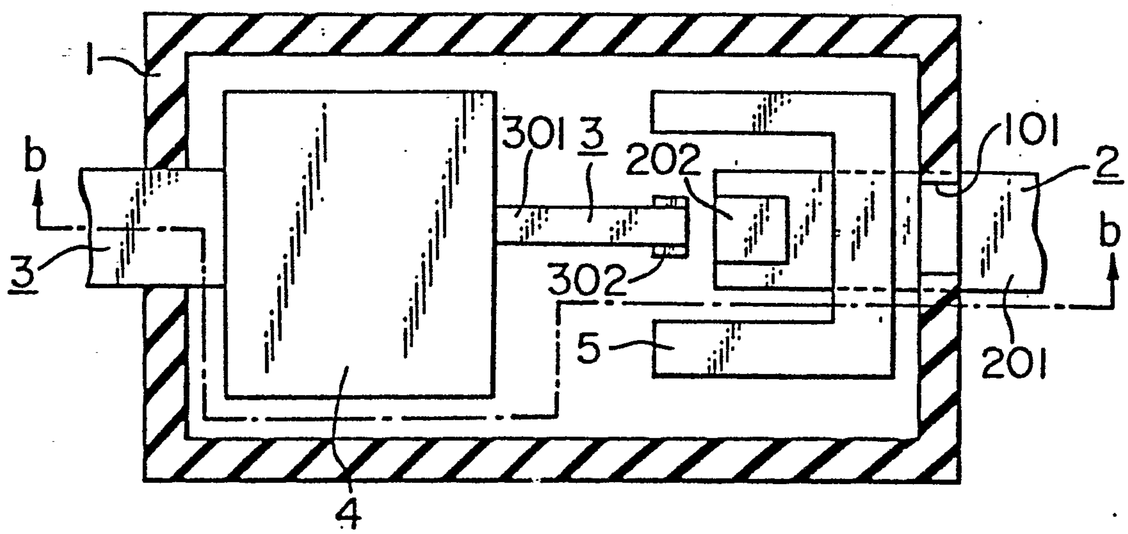


FIG. 1(b)

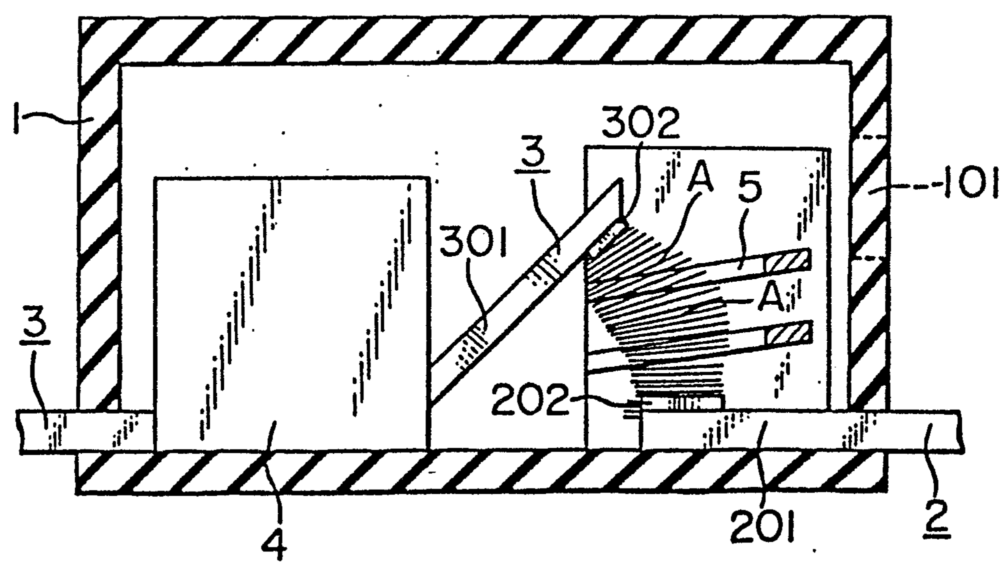


FIG. 2

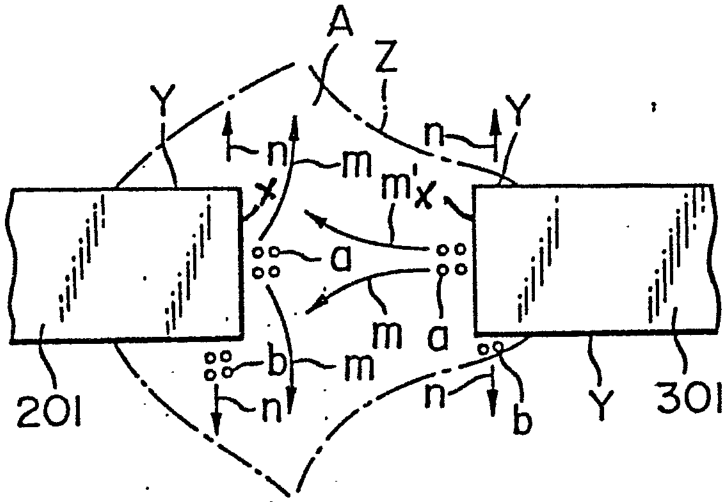


FIG. 3(a)

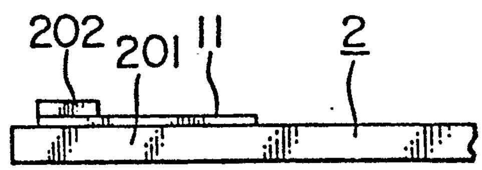


FIG. 3(c)

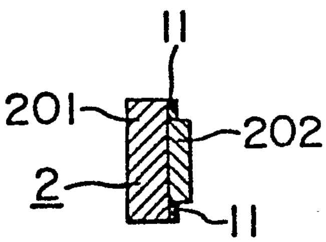


FIG. 3(b)

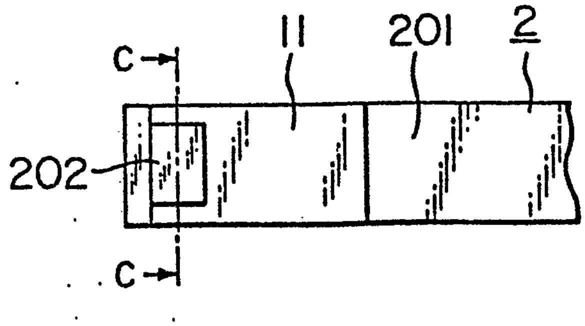


FIG. 4(a)

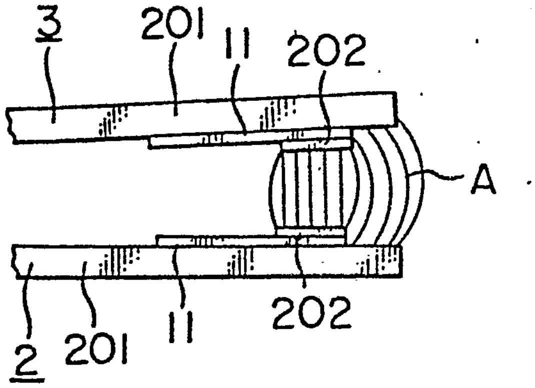


FIG. 4(b)

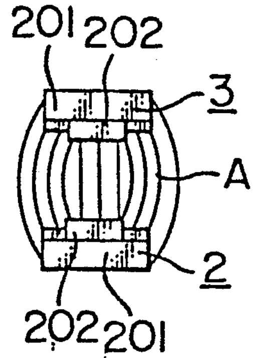


FIG. 5

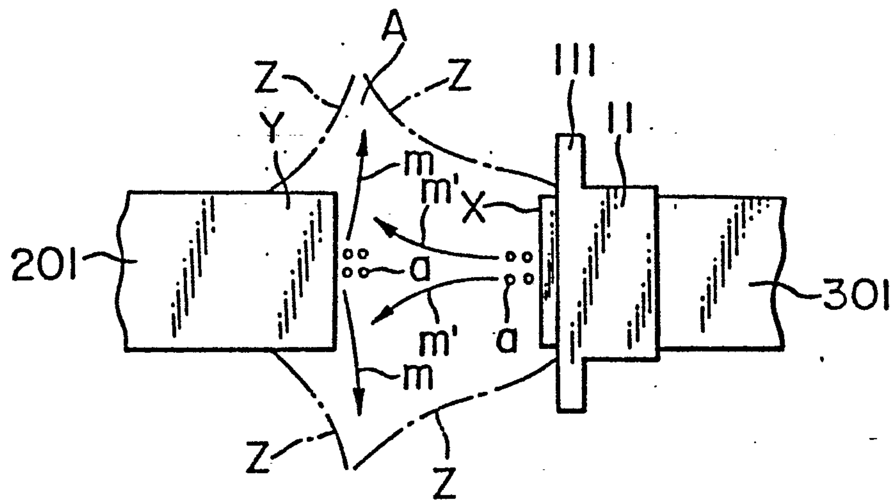
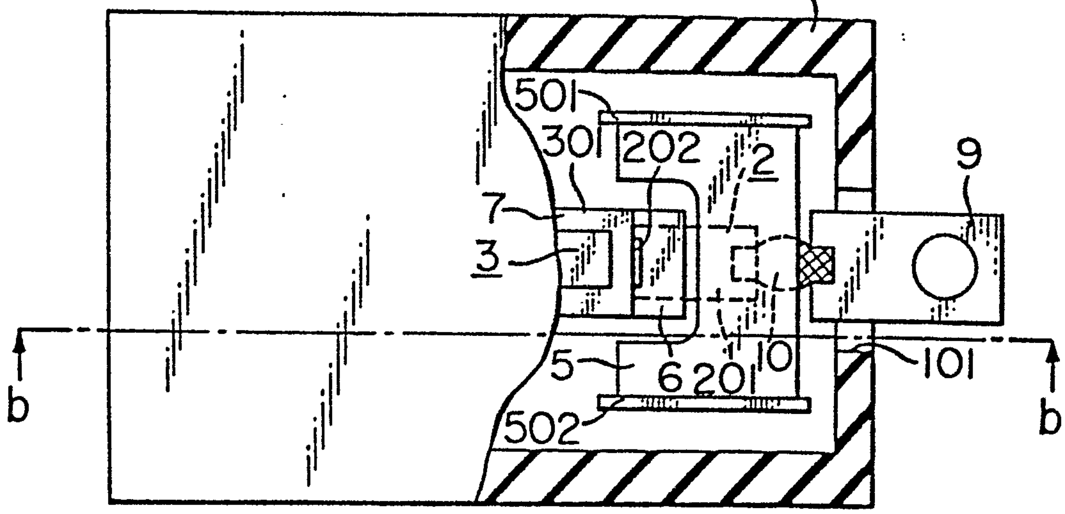


FIG. 6(a)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301
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7
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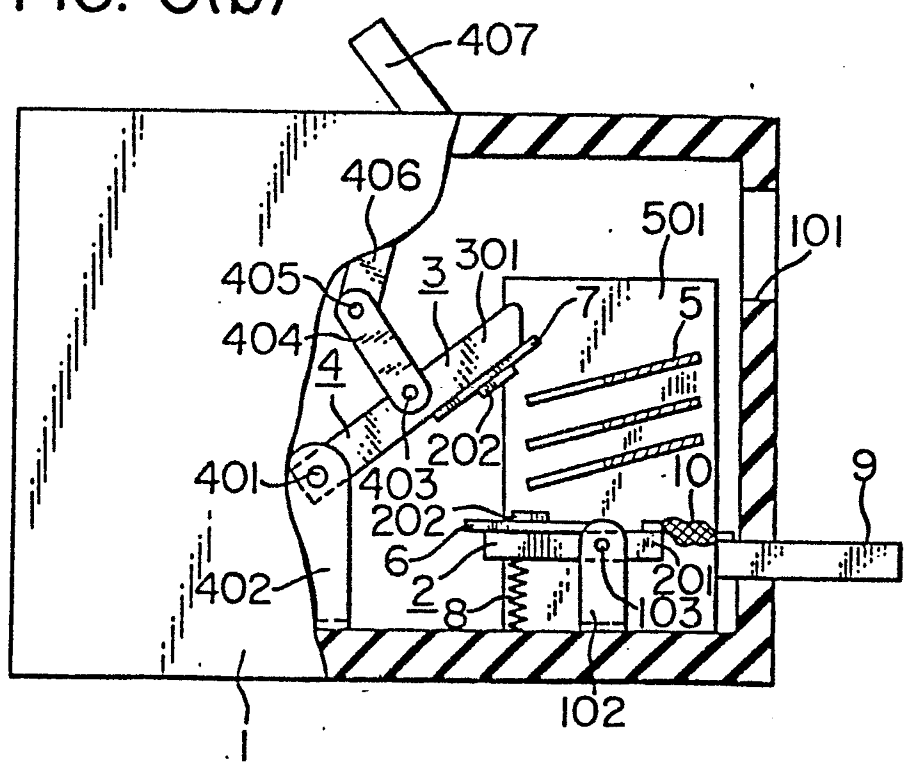
201
10
101
b
b
502

FIG. 6(b)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401
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103
1
102

FIG. 7

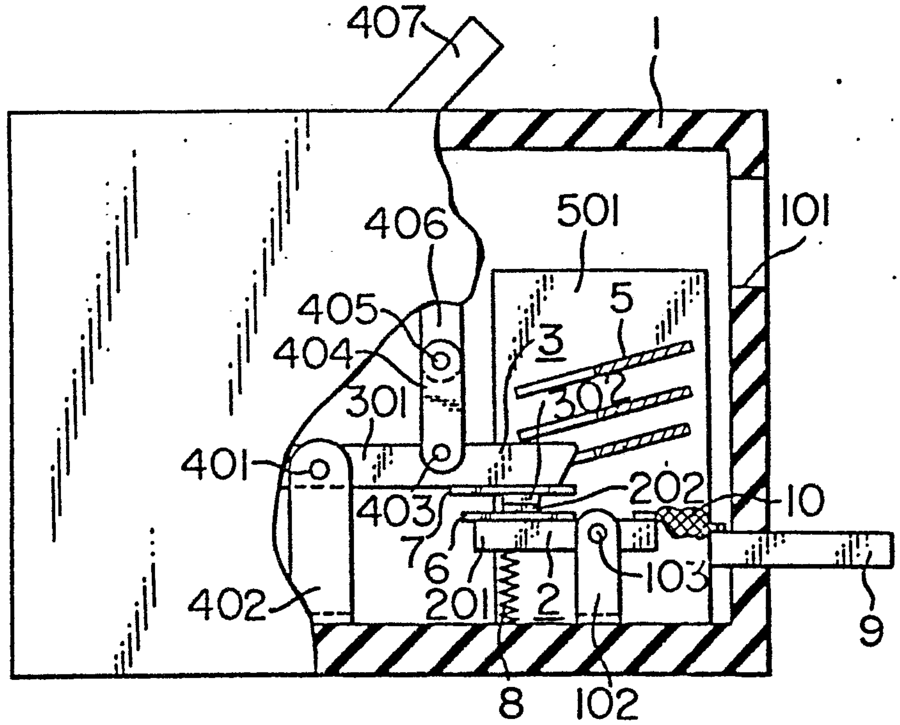
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FIG. 9

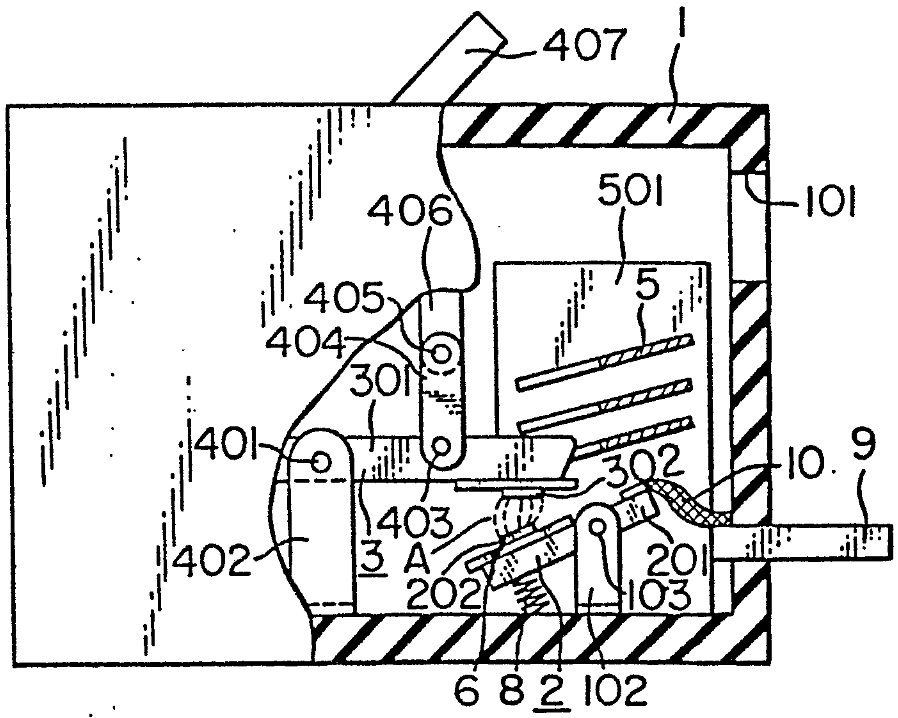
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FIG. 8

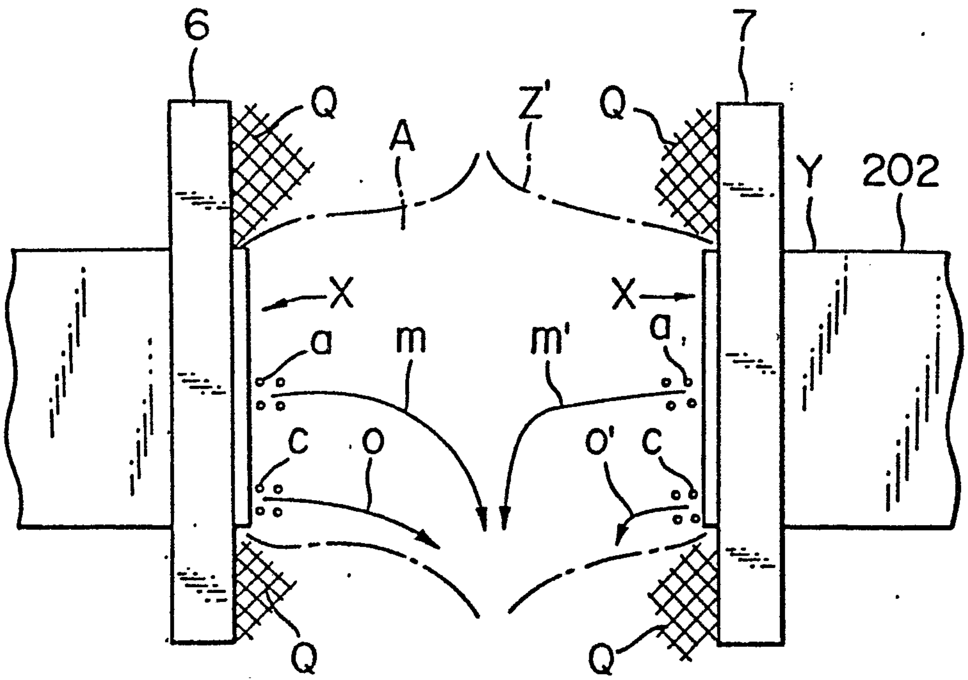


FIG. 11

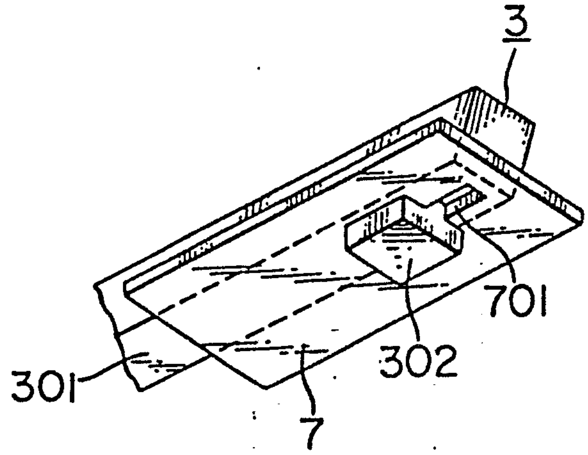


FIG. 10

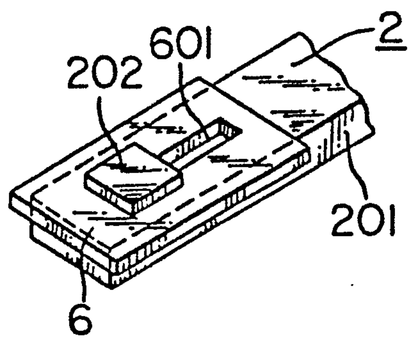


FIG. 12(a)

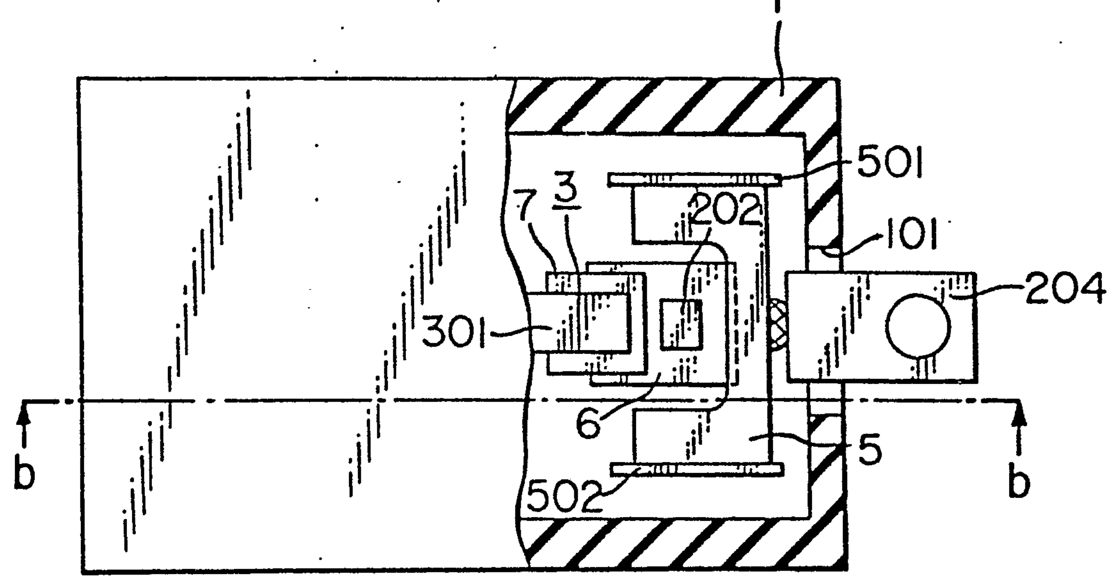


FIG. 12(b)

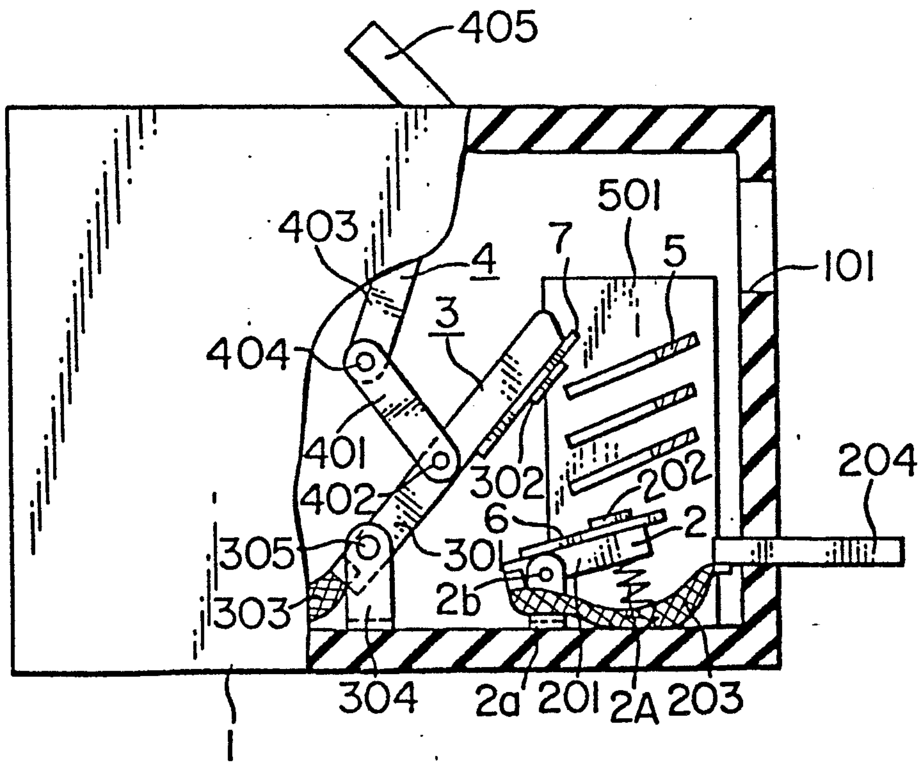
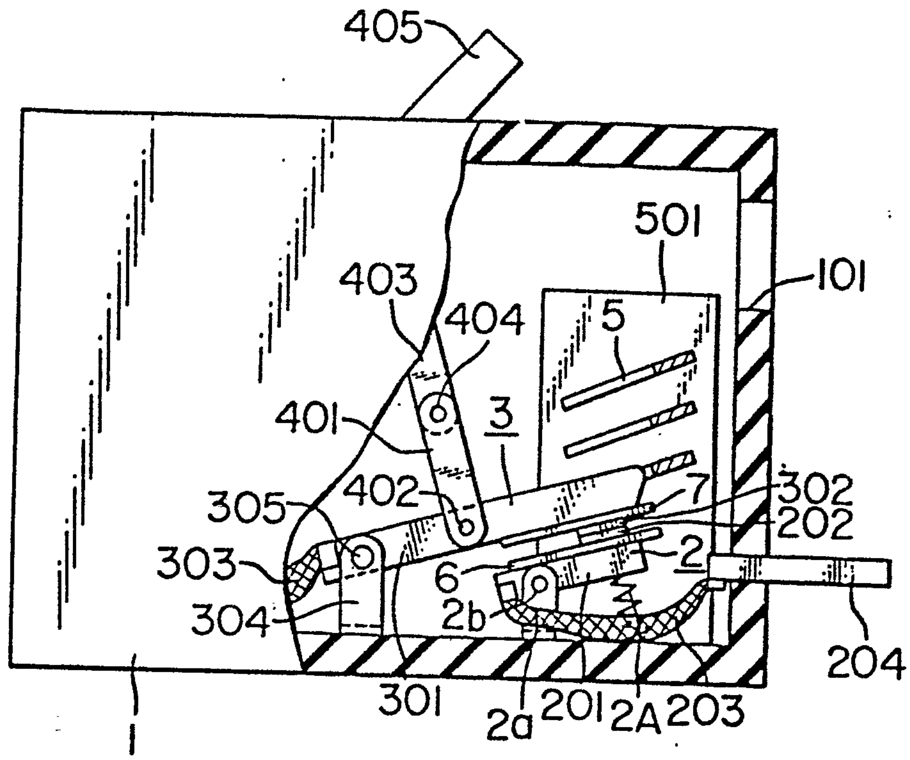


FIG. 13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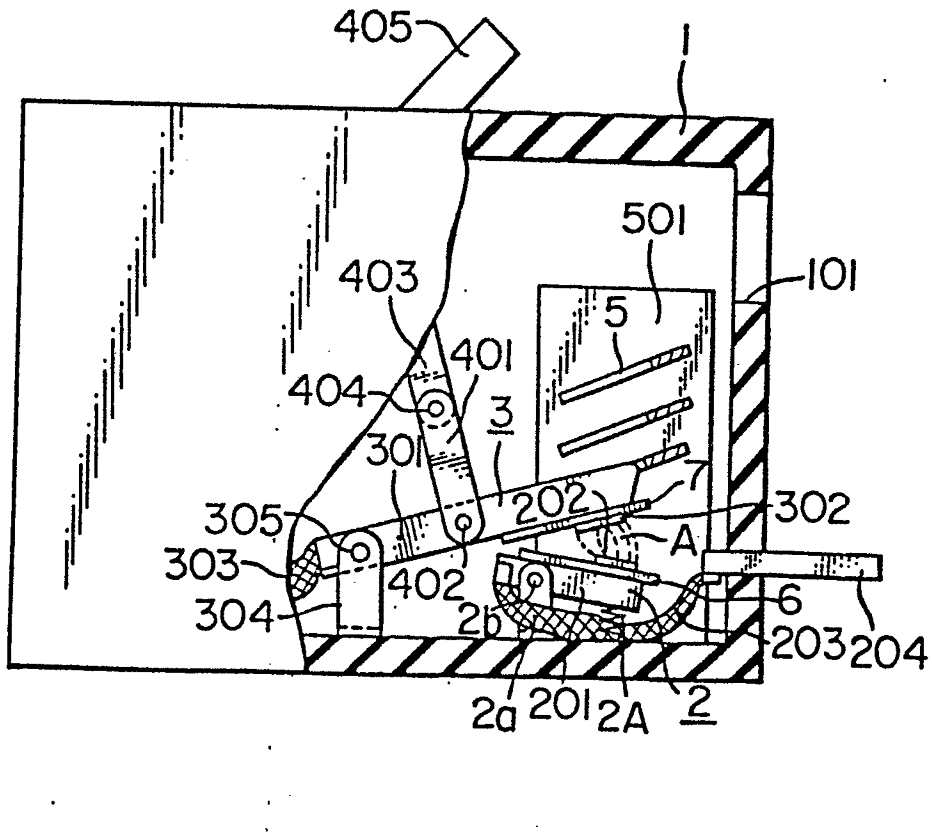
2a
201
2A
203
1

FIG. 14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2a
201
2A
2

FIG. 15(a)

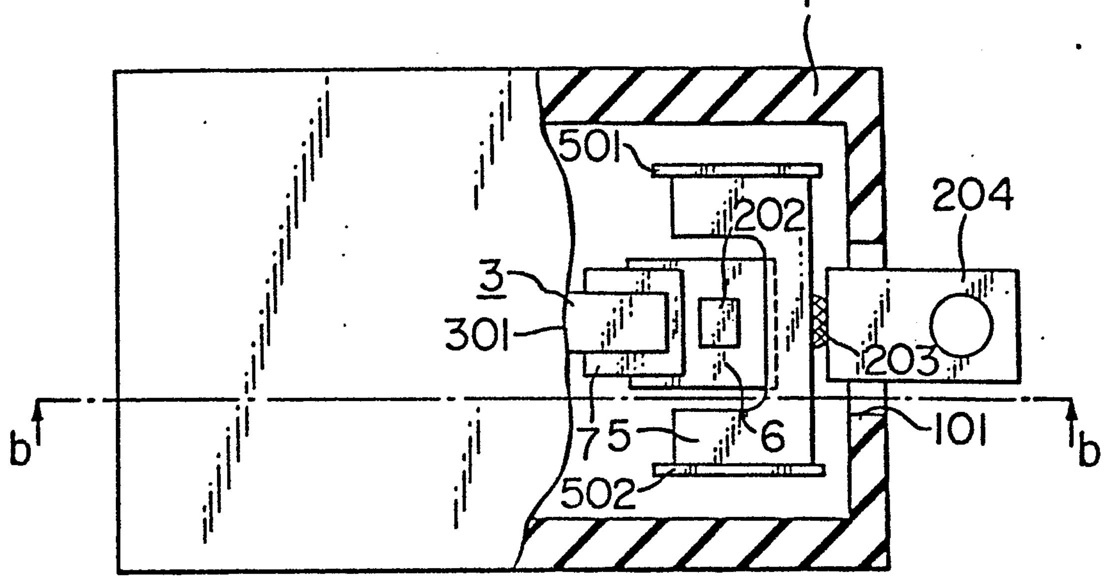

FIG. 15(b)

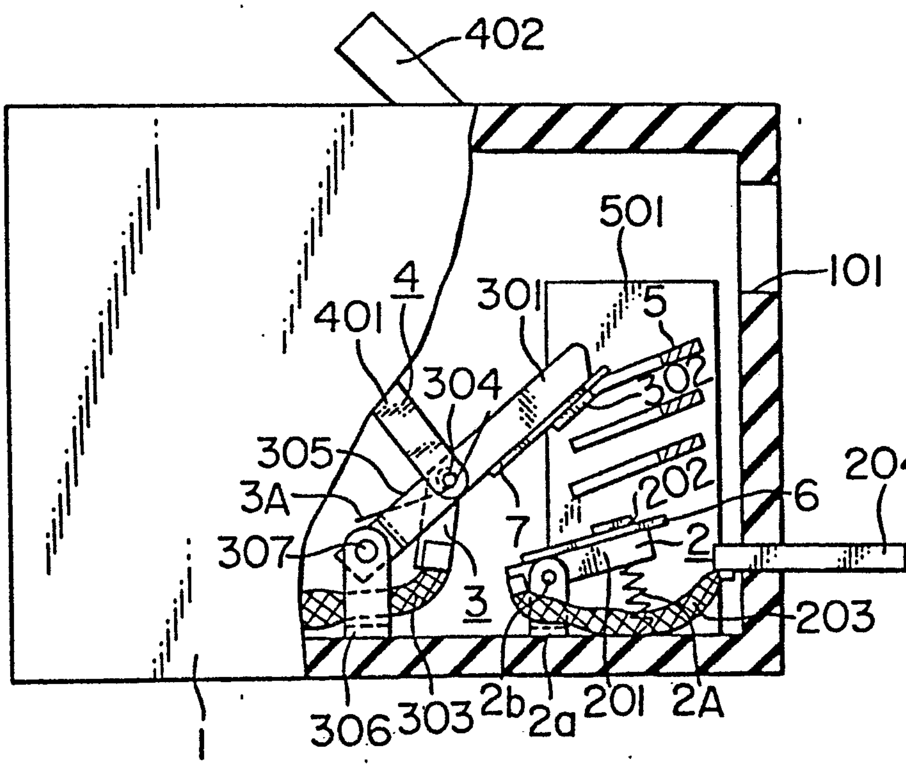

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FIG. 16

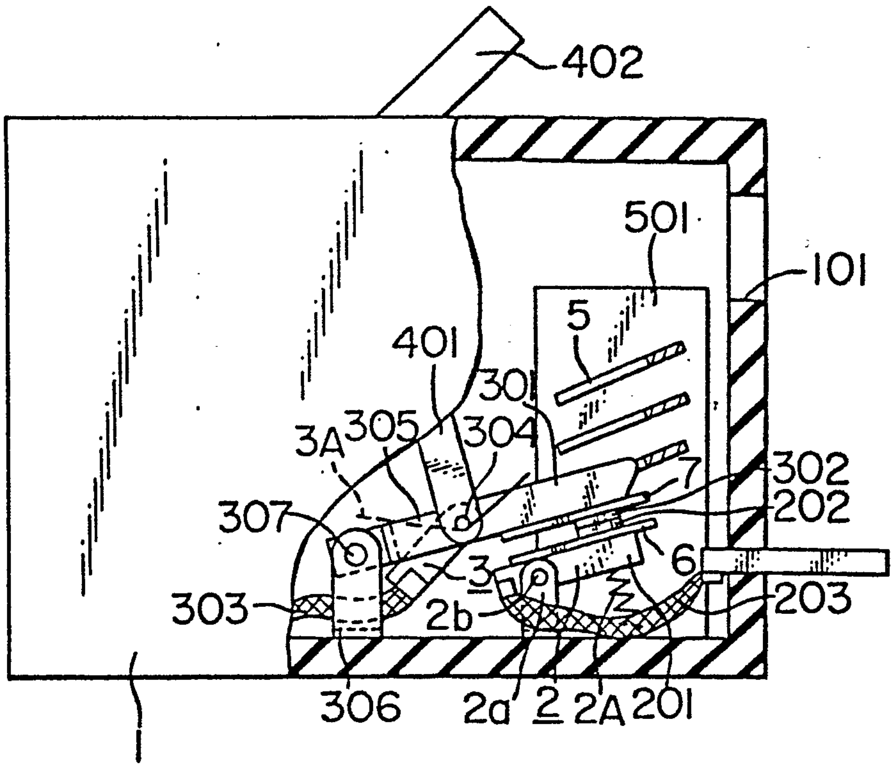


FIG. 17

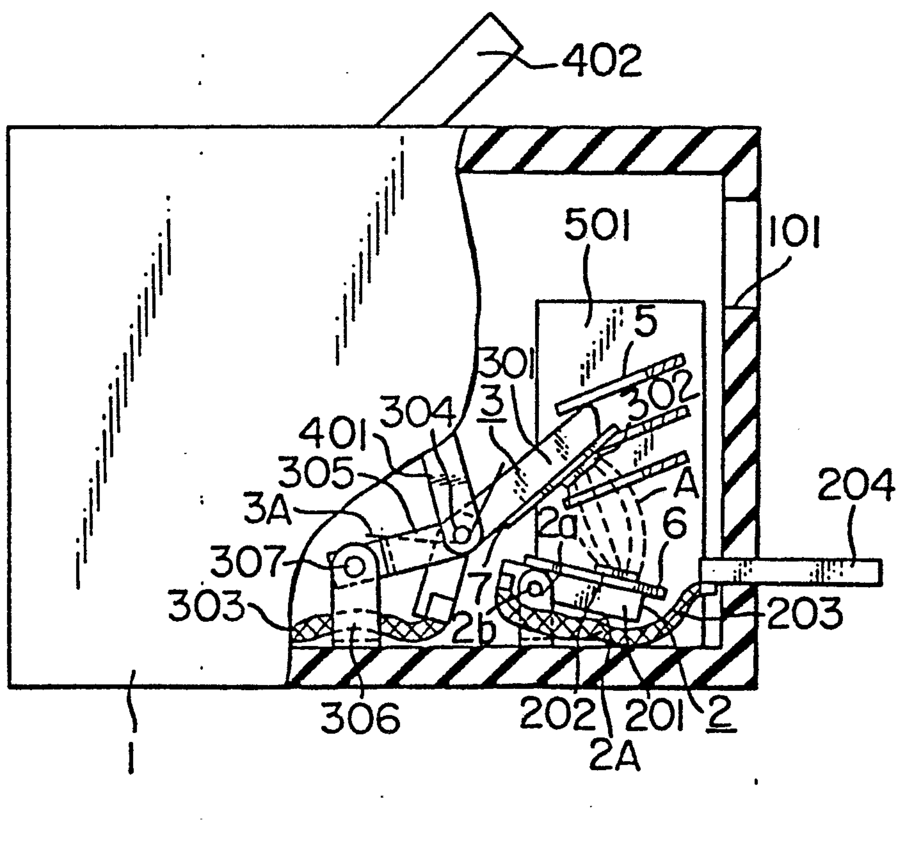


FIG. 18(a)

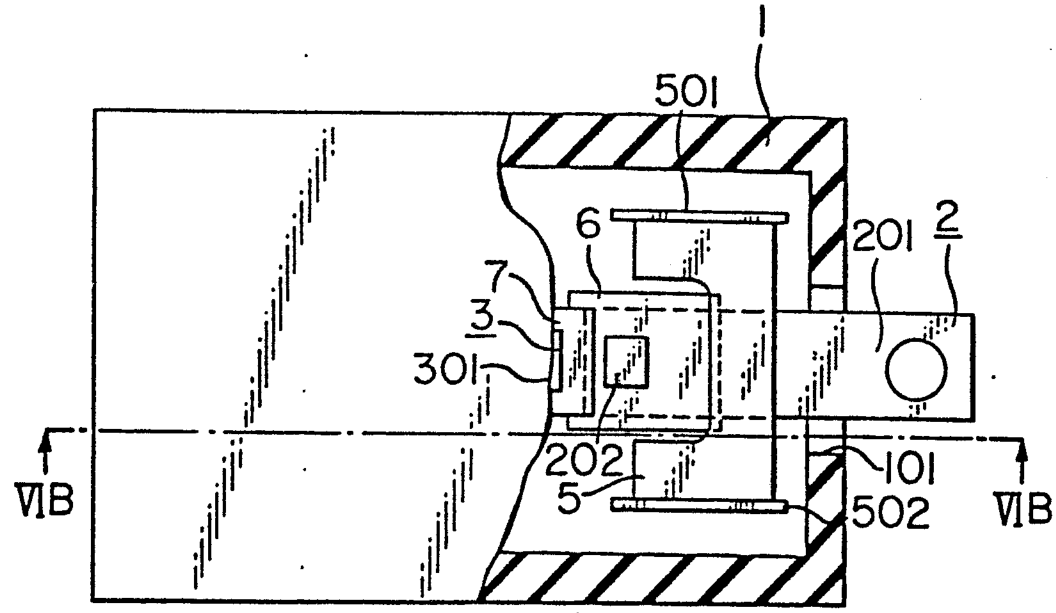


FIG. 18(b)

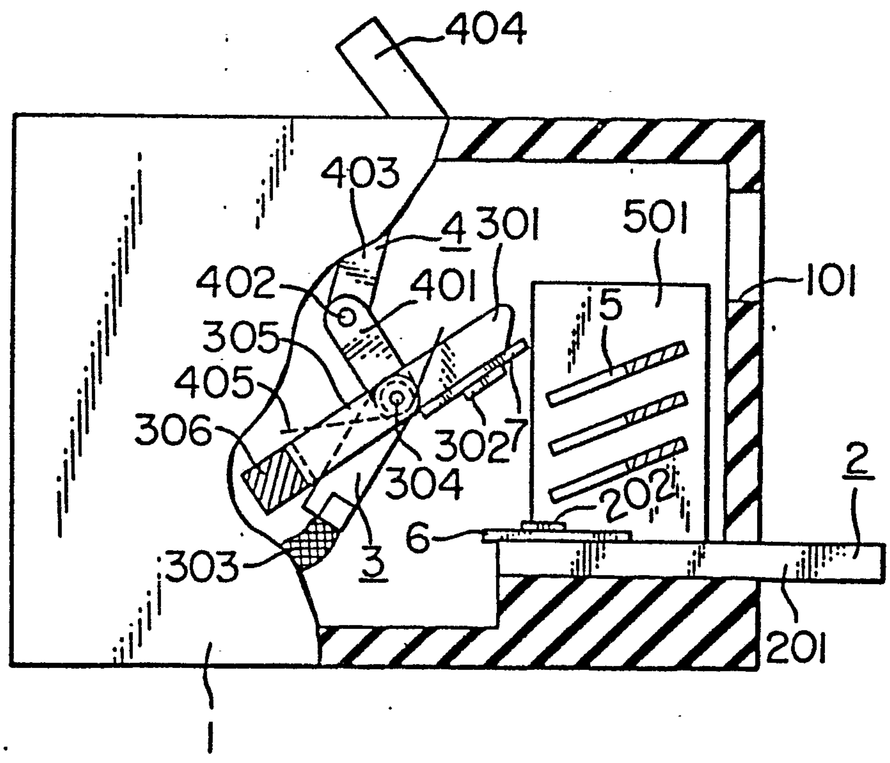
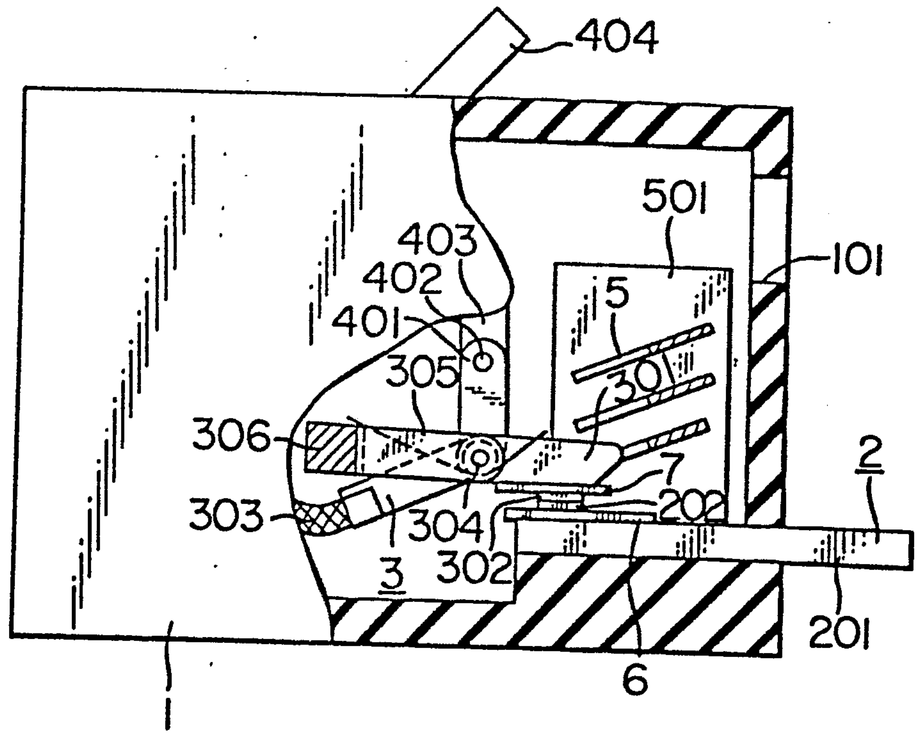


FIG. 19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306
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202
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304
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302
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201
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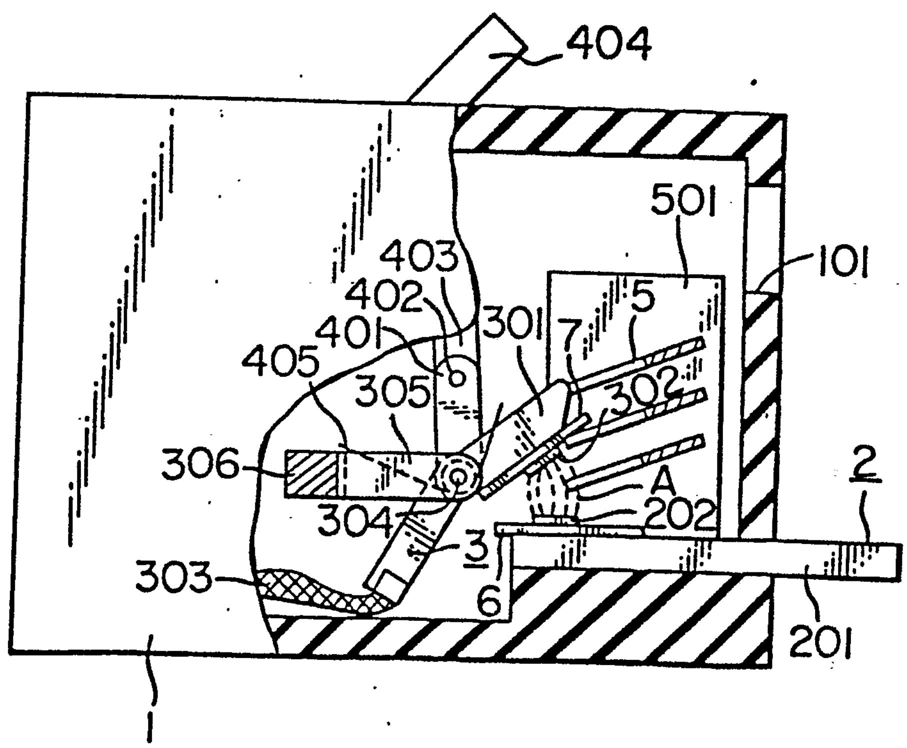
1

FIG. 20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306
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201
1

FIG. 21(a)

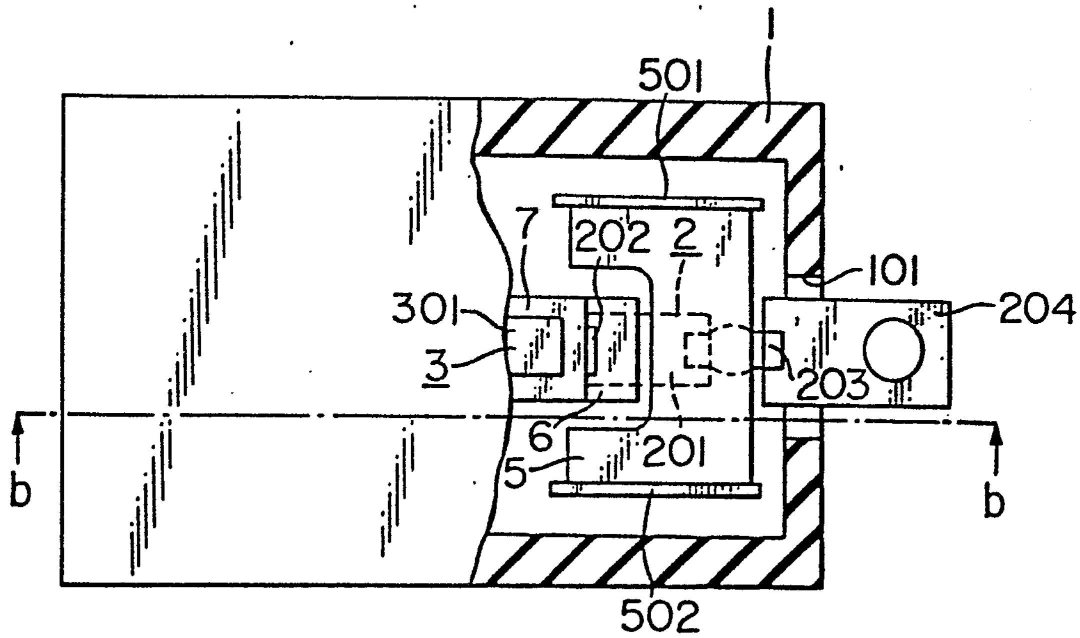


FIG. 21(b)

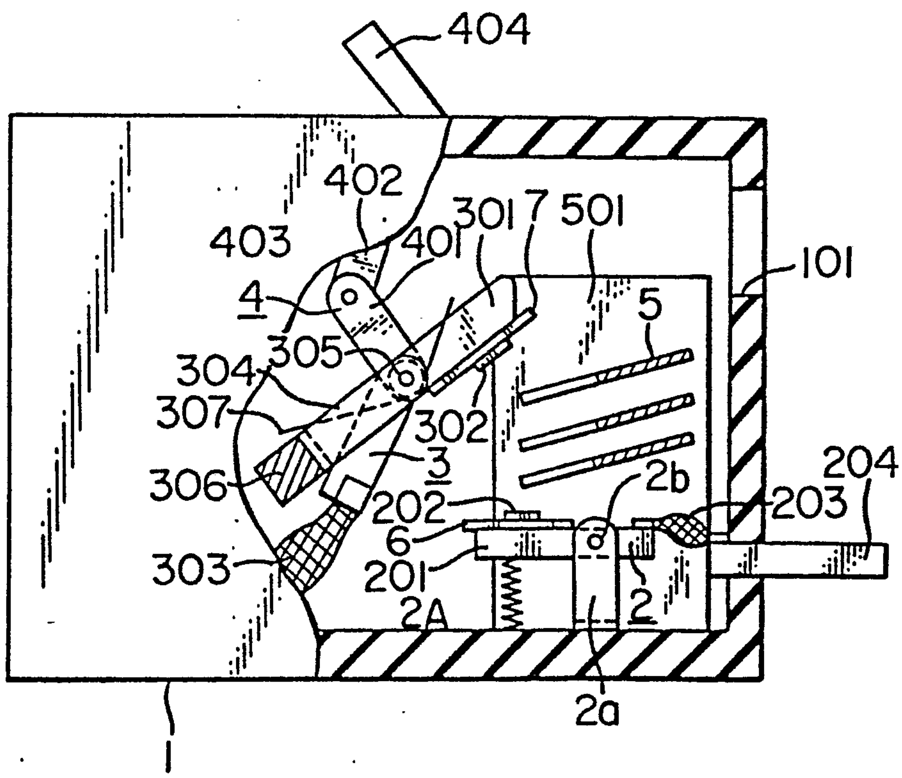


FIG. 22

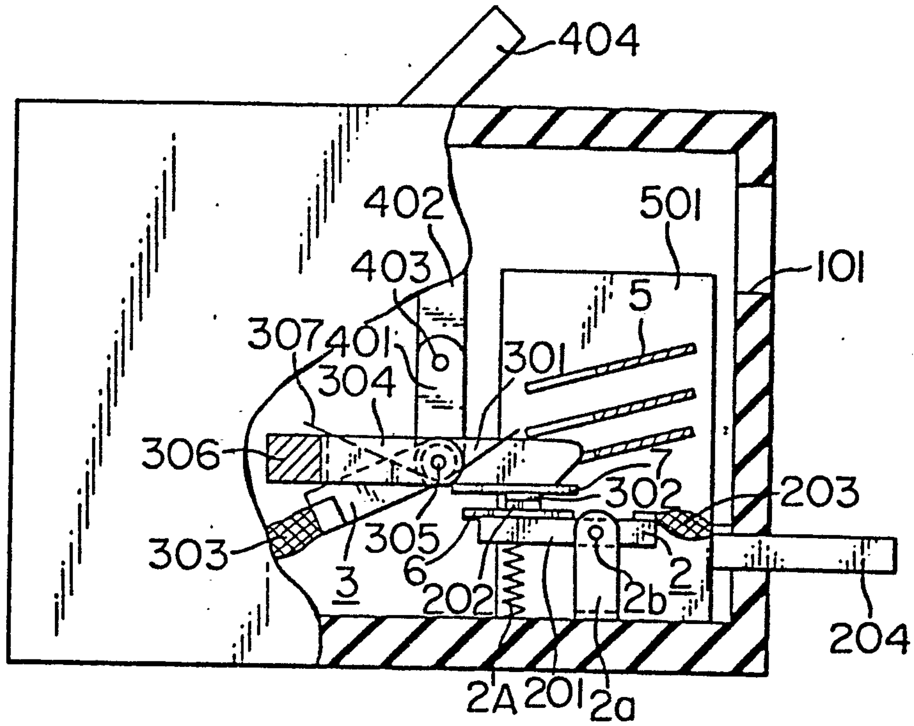
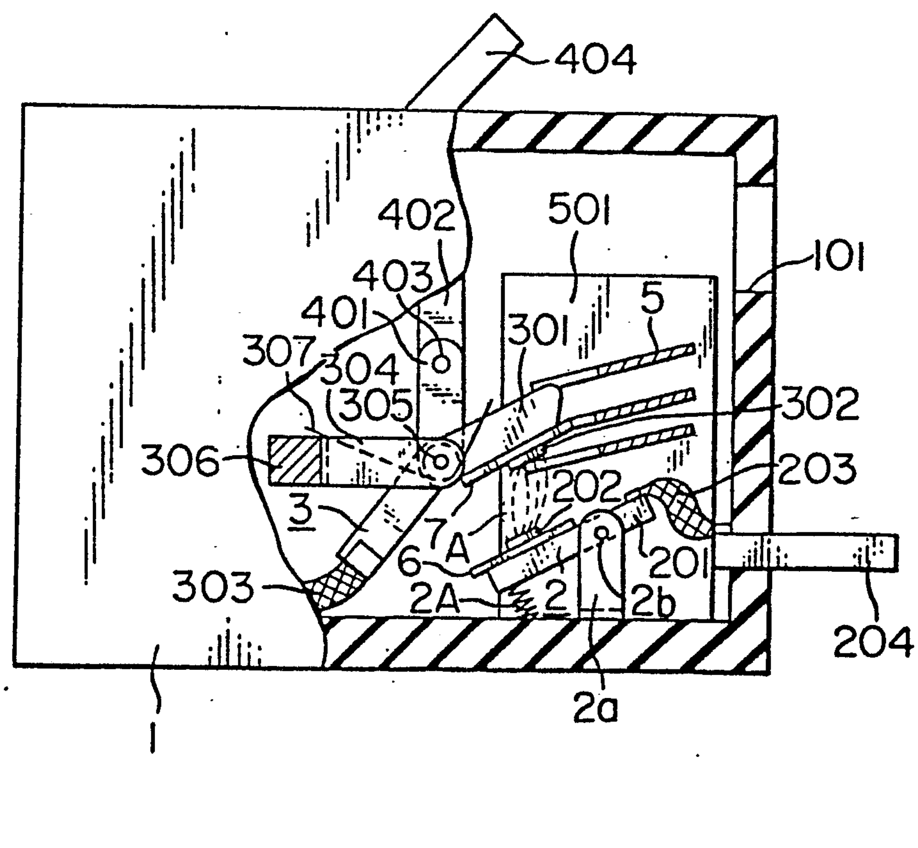

404
402
501
403
101
5
307
401
301
304
306
7
302
203
303
305
3
6
2
202
2b
204
2A
201
2a

FIG. 23


404
402
501
101
403
5
401
301
307
304
305
302
306
202
203
3
7
A
6
201
303
2A
2
2b
204
2a
1