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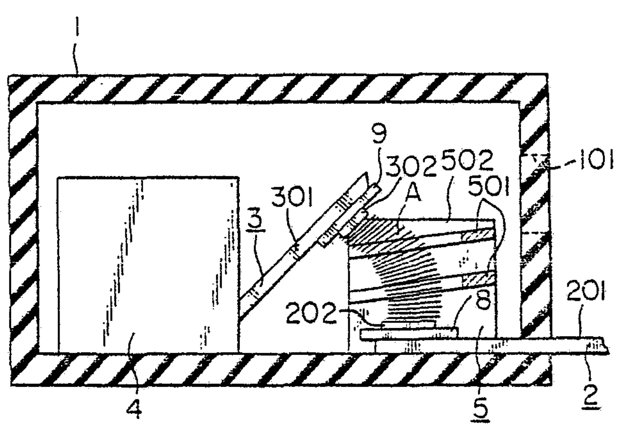
(54) Arc restricting device for a circuit breaker.

(57) This invention provides a novel circuit breaker of good current-limiting performance, and provides arc shields (8, 9) of a predetermined form surrounding contacts (202, 302) of a predetermined form, affixed to the rigid conductors (201, 301) of the contactors (2, 3) of a circuit breaker for opening and closing an electrical circuit, with the object of controlling the crosssectional shape and the length of an arc drawn between the contacts (202, 302) during tripping. The arc shields (8, 9) substantially project beyond the rigid conductors (201, 301) of the contactors (2, 3) in a direction which traverses the arc, and thus metal particles emitted from the contacts (202, 302) are effectively injected into the arc space, whereby the arc voltage is raised.



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CIRCUIT BREAKER

This invention relates to a circuit breaker and more particularly to a circuit breaker which offers enhanced current limiting performance during the tripping of the breaker.

In prior-art circuit breakers, it has been common practice to shift the arc into an arc extinguisher or to raise the separating speed of the contacts in order to quickly extinguish an electric arc struck across the gap between a pair of contacts during the interrupting operation. Such circuit breakers, however, suffer from the disadvantage that the foot of the arc struck across the gap between the contacts expands to fall onto the contactor conductors on which the contacts are mounted, and metal particles produced from the contact surfaces are not effectively injected into the arc space, so that the arc voltage, which relates to the extinction of the arc, is lowered.

It is an object of this invention to improve the current limiting performance of a circuit breaker by controlling the size and position of the foot of an electric arc struck across a gap between contacts such that the foot of the arc does not expand, and by effectively injecting the metal particles produced from the contacts into the arc space, whereby the arc voltage is raised.

This invention as claimed provides a circuit breaker comprising plate-form arc shields of a high resistivity material, surrounding the contacts provided on the rigid conductors of the contactors of a circuit breaker for making and breaking an electric circuit, and constructed such that the arc shields project substantially from the conductors in a lateral direction (i.e. the direction laterally traversing the arc).

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

Figure 1(a) is a sectional plan view of a conventional circuit breaker to which this invention is applicable;

Figure 1(b) is a sectional side view of the circuit breaker of Figure 1(a) taken along the dot-and-dash line b-b;

Figure 1(c) is a perspective view of an arc-extinguishing plate assembly which is disposed in the circuit breaker of Figure 1(a);

Figure 2 is a model diagram showing the behaviour of an electric arc which is struck across the gap between the contacts of the circuit breaker of Figure 1(a);

Figure 3(a) is a sectional plan view of a circuit breaker according to the present invention;

Figure 3(b) is a sectional side view of the circuit breaker of Figure 3(a) taken along the dot-and-dash line b-b;

Figure 4 is a model diagram showing the behaviour of an electric arc which is struck across the gap between the contacts of the circuit breaker shown in Figures 3(a) and (b);

Figure 5(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention, in which the plan of the arc shield resembles the plan of the contact and the planar central point of the arc shield is caused to coincide with the planar central point of the contact;

Figure 5(b) is a side view of the contactor of Figure 5(a);

Figure 6(a) is a plan view of a stationary contactor according to an embodiment of this invention wherein the contact is rectangular and the arc shield is circular in plan view;

Figure 6(b) is a side view of the contactor of Figure 6(a);

Figure 7(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the contact is circular and the arc shield is rectangular in plan view;

Figure 7(b) is a side view of the contactor of Figure 7(a);

Figure 8 is a plan view showing the cross-sectional shape of the arc in the embodiment of Figures 7(a) and (b);

Figure 9(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the planar central point of the arc shield is positioned at a point further from the arc extinguishing plate assembly than the planar central point of the contact;

Figure 9(b) is a side view of the contactor of Figure 9(a);

Figure 9(c) is a plan view of the contact portion of a movable contactor which pairs with the stationary contactor of Figure 9(a);

Figure 9(d) is a side view of the contactor of Figure 9(c);

Figure 10(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the arc shield is formed with a concave surface;

Figure 10(b) is a side view of the contactor of Figure 10(a);

Figure 11(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the arc shield is formed with a convex surface;

Figure 11(b) is a side view of the contactor of Figure 11(a);

Figure 12(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the surface confronting the arc is given an inclination;

Figure 12(b) is a side view of the contactor of Figure 12(a);

Figure 13(a) is a plan view of the contact portion of a stationary contactor according to an embodiment of this invention wherein the width of the contact narrows towards the arc extinguishing plate assembly or the gas exhaust ports of the circuit breaker; and

Figure 13(b) is a side view of the contactor of Figure 13(a).

In the drawings, identical reference numerals denote similar or corresponding parts.

Description will now be made of a conventional circuit breaker to which this invention is applicable, with reference to Figures 1(a), (b) and (c).

An enclosure 1 is made of an insulating material, forming the housing for a switching device, and is provided with an exhaust port 101. A stationary contactor 2 housed in the enclosure 1 comprises a stationary rigid conductor 201 which is rigidly fixed to the enclosure 1, and a stationary-side contact 202 which is mounted on one end of the stationary rigid conductor 201. A movable contactor 3 which is adapted to engage the stationary contactor 2 comprises a movable rigid conductor 301 which makes or breaks contact with the stationary rigid conductor 201, and a movable-side contact 302 which is mounted on one end of the movable rigid conductor 301 in opposition to the stationary-side contact 202. An operating mechanism 4 operates to move the movable contactor 3 in or out of contact with the stationary contactor 2. An arc-extinguishing plate assembly 5 functions to extinguish an electric arc A struck upon the separation of the movable-side contact 302 from the stationary-side contact 202, and it is so constructed that a plurality of arc-extinguishing plates 501 are supported by frame plates 502. The arc-extinguishing plates 501 are usually formed of a magnetic material such as iron.

Although, for the sake of simplicity of illustration, the arc-extinguishing plates 501 are illustrated in numbers of two and four in Figures 1(b) and 1(c), respectively, it is to be understood that actually the number of arc-extinguishing plates 501 in the arc-extinguishing plate assembly 5 may be as high as, for example, ten plates.

The operating mechanism 4 and the arc-extinguishing plate assembly 5 are well known in the art, and are described, for example, in US-PS 3,599,130. As is apparent from this patent, the operating mechanism includes a reset mechanism.

Assuming now that the movable-side contact 302 and the stationary-side contact 202 are closed, current flows from a power supply side onto a load side along a path from the stationary rigid conductor 201, to the stationary-side contact 202, to the movable-side contact 302, to the movable rigid contactor 301. When, in this state, a high current such as a short-circuit current flows through the circuit, the operating mechanism 4 operates to separate the movable-side contact 302 from the stationary-side contact 202. At this time, an arc A appears across the gap between the stationary-side contact 202 and the movable-side contact 302, and an arc voltage develops thereacross. The arc voltage rises as the distance of separation of the movable-side contact 302 from the stationary-side contact 202 increases. In addition, since the arc-extinguishing plates 501 are made of a magnetic material and have a reluctivity much lower than that of the surrounding space, a magnetic flux induced by the current of the arc A is attracted in the direction

V (Figure 1(b)) of the arc-extinguishing plates 501. Accordingly, the arc A is drawn toward the arc-extinguishing plates 5 and is stretched, whereby the arc voltage rises even further.

As a means for driving the arc toward the arc-extinguishing plate assembly 5, a method utilizing an air current is also well known, in addition to the above method utilizing a magnetic field. More specifically, the arc is driven by the air current which is created when the air in the enclosure 1 is raised in temperature and pressure by the energy of the arc A and is discharged through the exhaust port 101. As a means for driving the arc utilizing a magnetic field, in addition to the above described method employing arc-extinguishing plates 501, also well known are a method employing a blowout coil, a blowout magnet, or a permanent magnet; a method utilizing a parallel current which flows in the reverse direction across the stationary rigid conductor 201 and the movable rigid conductor 301, etc.

In the manner described above, the arc current reaches the current zero point to extinguish the arc A, so that the interruption is completed. Where the power supply is a D.C. power supply, an arc voltage greater than the supply voltage is generated, whereby a current limiting action is effected and the current zero point is forcibly established. With a D.C. power supply, accordingly, a phenomenon similar to that in the case of the foregoing A.C. current zero point occurs. During the interrupting operation thus far described, large quantities of energy are generated by the arc A across the gap between the movable-side contact 302 and the stationary-side contact 202 in a short period of time of the order of several milliseconds. In consequence, the temperature of the gas within the enclosure 1 rises abruptly, as does the pressure thereof, and the high-temperature and pressure gas is emitted into the atmosphere through the exhaust port 101.

As the circuit breaker performs the interrupting operation as described above, the operations of the stationary-side contact 202 and the movable-side contact 302 can be analyzed as follows. In general, the arc resistance R(Ω) is given by the following expression:

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

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

In general, in short arc A with a high current of at least several kA and an arc length ℓ of at most 50 mm, the arc space is occupied by particles of metal from the rigid conductors on which the arc has its foot. Moreover, the emission of metal particles from the rigid conductors occurs orthogonally to the rigid conductor surfaces. At the time of the emission, the emitted metal particles have a temperature close to the boiling point of the metal used in the rigid conductors. When injected into the arc space, the metal particles possess a conductivity due to the electrical energy of the arc and they are also further raised in temperature by the arc, and flow away from the rigid conductors at high speed while expanding in a direction conforming with the pressure distribution in the arc space. The arc resistivity ρ and the arc sectional area S in the arc space are determined by the quantity of metal particles produced and the direction of emission thereof. Accordingly, the arc voltage is determined by the behaviour of such metal particles.

Figure 2 is a model diagram to illustrate the behaviour of the metal particles. As shown, a pair of rigid conductors 6 and 7 are ordinary conductors in the form of mutually opposed metallic cylinders. The rigid conductor 6 is an anode, while the rigid conductor 7 is a cathode. The surfaces X of the respective rigid conductors 6 and 7 are opposing surfaces which become contact surfaces when the rigid conductors 6 and 7 come into contact, and the surfaces Y of the respective rigid conductors 6 and 7 are the surfaces of the rigid conductors other than the opposing contact surfaces X. The description of the behaviour of the metal particles to be given below also applies similarly to a case where the surfaces X are formed of the contact members. The contour Z indicated by a dot-and-dash line in the figure is the envelope of the arc A struck across the gap between the rigid conductors 6 and 7. Further, metal particles b are typically representative of the metal particles which are respectively emitted from the surfaces X and Y of the conductors 6 and 7 by vaporization, etc. The directions of emission of the metal particles a and b are the directions of the flow lines indicated by arrows m, m' and n, n', respectively.

Such metal particles a and b emitted from the rigid conductors 6 and 7 have their temperature raised by the energy of the arc space from approximately 3,000°C, the boiling point of the metal of the rigid conductors, to a temperature at which the metal particles bear conductivity, i.e., at least 8,000°C, or up to an even higher temperature of approximately 20,000°C. As the temperature rises, the metal particles take energy out of the arc space and thus lower the temperature of the arc space, resulting in increased arc resistance R. The quantity of energy taken from the arc space by the metal particles a and b increases with the rise in the temperature of the metal particles. In turn, the rise in the temperature is determined by the positions and emission paths of the metal particles a and b emitted from the rigid conductors 6 and 7. Further, the paths of the metal particles a and b emitted from the rigid conductors 6 and 7 are determined by the pressure distribution in the arc space. The pressure in 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 current density. In other words, it is determined by the size of the foot of the arc A on the rigid conductors 6 and 7. In general, the metal particles and b may be considered to fly in the space determined by the pinch force while thermally expanding. It is also known that, in a case where the size of the foot of the arc A on the rigid conductors 6 and 7 is not limited, the metal particles a are blown unidirectionally from one rigid conductor 7 to the other rigid conductor 6 in the form of a vapor jet. When in this manner the metal particles a move unidirectionally from one rigid conductor 7 toward the other rigid conductor 6, the metal particles a to be injected into the positive column of the arc A are supplied substantially from only the rigid conductor on one side 7. Figure 2 illustrates by way of example a case where the metal particles are blown strongly from the cathode to the anode, but they may also be blown in the opposite direction.

The above phenomenon will now be described in greater detail. In Figure 2, it is supposed that the blowing, for whatever reason, is unidirectional from the rigid conductor 7 toward the rigid conductor 6. The metal particles a starting from the surfaces X, being the surface of the rigid conductor 7 opposing the rigid conductor 6, tend to fly orthogonally to the rigid conductor surfaces or, in other words, toward the positive column of the arc. At this time, a metal particle a which begins its flight from the contact surface X of one rigid conductor 7 is injected into the positive column by pressure caused by the pinch force. In contrast, a metal particle a which begins its flight from the contact surface X of the other rigid conductor 6 is pushed by the particle stream in the positive column and is ejected outside the contact surface X, immediately being forced out of the system without entering the positive column. In this manner, the flights of the metal particle a emitted from the rigid conductor 6 and of the metal particle a emitted from the rigid conductor 7 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 at the rigid conductor surface. Thus, the unidirectional blowing from the rigid conductor 7 heats the rigid conductor 6 on the blown side and expands the foot (anode spot in some cases, and cathode spot in others) of the arc on the surface of the rigid conductor 6 from the front surface X thereof to the other surface thereof. In consequence, the current density on the surface of the conductor 6 lowers, as does the pressure of the arc. Accordingly, the unidirectional blowing from the rigid conductor 7 is increasingly intensified. The discrepancy in the flight paths of the metal particles a emitted from the respective rigid conductors 6 and 7 as has thus occurred results in a discrepancy in the quantities of energy that the particles of both the conductors take from the arc space. More specifically, a metal particle a blown from the contact surface X of the rigid conductor 7 is able to absorb substantial energy from the positive column, whereas a metal particle a blown from the contact surface X of the rigid conductor 6 is not, and so it is ejected out of the system without effectively cooling the arc A. On the other hand, metal particles b emitted from the surfaces Y of the respective rigid conductors 6 and 7 spread transversely as indicated by the flow lines of the arrows n and n' in Figure 2. Therefore, they do not deprive the arc A of substantial heat. Moreover, they increase the arc sectional area S, resulting in lowered resistance R of the arc A.

In this manner, in the instance of blowing from one rigid conductor 7, the efficiency of the cooling of the positive column by the metal particles a from the other rigid conductor 6 is reduced. In addition, the metal particles b emitted from the surfaces Y of both the rigid conductors 6 and 7, being those surfaces other than the opposing contact surfaces, do not contribute to the cooling of the positive column at all and may even lower the arc resistance R by increasing the arc sectional area S. Accordingly, the presence of the unidirectional blowing of the metal particles from one rigid conductor to the other is impedimental to raising the arc voltage and renders it impossible to enhance the current-limiting performance during tripping.

There are, however, several disadvantages in that, in general, the stationary contactor and the movable contactor used in conventional circuit breakers have large opposing surface areas, similar to the conductors of the model of Figure 2, making it impossible to limit the size of the foot of the struck arc. Moreover, the contactors have exposed surfaces such as peripheral surfaces in addition to the opposing surfaces, so that, as explained with reference to Figure 2, the position and size of the foot(anode spot or cathode spot) of the arc appearing on the surfaces of the two conductors cannot be limited. Furthermore, the unidirectional blowing of the metal particles a from one contactor to the other occurs, with the result that the arc sectional area increases as explained with reference to Figure 2, such that the current-limiting performance during tripping cannot be enhanced, as stated above.

As appears from the foregoing, in order to enhance the current-limiting performance of a circuit breaker, the arc voltage has to be raised, and to this end, the metal particles appearing in the foot 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. The pinch force changes greatly in accordance with the size of the foot of the arc on the contactors, or with the current density. It is accordingly possible to control the pinch force. In conventional contactors, the area of the surfaces X of the conductors is large, which fact effectively prevents a limitation of the size of the foot of the arc. When the opposing contact surfaces X of both the contactors are made sufficiently small, the density of current on the contact surfaces X rises substantially, increasing the pinch force. Accordingly, metal particles are injected from both sides into the positive column, unlike to the prior-art circuit breaker, so that the arc voltage becomes higher than in the prior device. With this measure alone, however, the spread of the foot of the arc to parts other than the contact surfaces X or to the surfaces Y cannot be restrained, and the current density on the contact surfaces X decreases by a component corresponding to the spread of the foot of the arc to the surfaces Y, so that the metal particle injection pressure lowers. With the contactors of the prior art, accordingly, the cooling effect on the positive column by the injection of metal particles is not the maximum possible.

Further, in the contactors of the prior art, the spread of the foot of the arc to the surface Y leads to the disadvantage that the foot of the arc is liable to spread directly to the interfacing point between the contact and the conductor which is often set on the surface Y, and a joint member of a low fusing point may be melted by the heat of the arc making the contact liable to fall off.

Now, the invention relates to a circuit breaker which provides good current-limiting performance in the interruption of excess currents such as accompany electric faults, and which also has a high arc voltage, and yet in which the problem of the contacts falling off is eliminated.

With a circuit breaker according to this invention, the above and other objects can be achieved by covering and concealing the portions of the rigid conductors in the vicinity of the contacts behind arc shields of a high resistivity material with a higher resistivity than the material forming the rigid conductors (hereinbelow simply called high resistivity material), leaving a portion of the electrical contact surface of the contacts of the circuit breaker, whereby the metal particles will be forcibly injected into the arc space, and wherein the arc shields are of a predetermined form. As the high resistivity material for the arc shields, organic or inorganic insulators as well as high resistivity alloys or metals, such as copper-nickel, copper-manganese, manganin, iron-carbon, iron-nickel and iron-chromium, may be used. It is also possible to use iron the resistivity of which increases abruptly with temperature.

Hereinbelow, an embodiment showing the basic construction of this invention is taken as an example to serve in an explanation of the basic construction of this invention.

Figures 3(a) and 3(b) are respectively a sectional plan view and a sectional side view of an embodiment showing the basic construction of this invention. Parts of the circuit breaker other than the stationary contactor 2 and the movable contactor 3 are constructed similarly to the corresponding parts of the circuit breaker of the prior art shown in Figures 1(a), 1(b) and 1(c), and so description thereof will not be repeated. The dimensions to be mentioned hereinbelow relate to a circuit breaker in which the rated current is 100 A.

As shown in Figures 3(a) and 3(b), the stationary contactor 2 is constructed with a stationary rigid conductor 201, an arc shield 8 and a stationary-side contact 202. The plate-form stationary rigid conductor 201 is made of an electrically conductive material, such as copper, and in the described embodiment it is formed with a width of 8 mm, while the thickness is 3,2 mm. The lower surface of the stationary rigid conductor 201 is fastened to the enclosure 1. The stationary-side contact 202 is made of a silver alloy contact material, and is formed in the shape of a rectangular block with a square base of 4,5 mm sides and a height of 3,5 mm. The bottom surface of the stationary-side contact 202 is fastened to the top surface of the stationary rigid conductor 201 near the fore end thereof. The silver alloy contact material may contain tungsten carbide (WC) or iridium. The arc shield 8 is made of a high resistivity material as above described, or an insulating material such as a phenol resin or a ceramic. It is formed in a plate form of regular square plan with sides of 12 mm, while the thickness is 2 mm. Centrally of the arc shield 8 is provided a square through-hole of sides of approximately 4,5 mm in length, corresponding to the stationary-side contact 202, and the stationary-side contact 202 projects through this hole. In this way, the arc shield 8 not only covers the upper surface of the stationary rigid conductor 201 in the vicinity of the stationary-side contact 202, but it also substantially projects horizontally beyond the sides or edges of the stationary rigid conductor 7.

Further, as shown in Figures 3(a) and 3(b), the movable contactor 3 is constructed with a movable rigid conductor 301, a movable-side contact 302, and an arc shield 9, each of which is respectively constructed of the same materials as the corresponding portions of the stationary contactor 2. The movable rigid conductor 301 is formed in a rod shape of 3,2 mm thickness and 3,2 mm width, and to its lower surface near the fore end thereof is affixed the upper surface of the movable-side contact 302. The movable side contact is formed in the shape of a rectangular block with a square base of 3,2 mm sides, and a height of 3,5mm. The arc shield 9 is formed in a plate form of regular square plan with sides of 7,5 mm, while the thickness in 2 mm. Centrally of the arc shield 9 is provided a square through-hole of sides of approximately 3,2 mm length, corresponding to the movable-side contact 302 which projects therethrough. In a manner similar to the arc shield 8 on the side of the stationary contactor 2, the arc shield 9 substantially projects horizontally beyond the sides or edges of the movable rigid conductor 301.

Assuming now that the movable-side contact 302 and the stationary-side contact 202 are closed, current flows from a power supply side onto a load side along a path from the stationary rigid conductor 201 to the stationary-side contact 202, to the movable-side contact 302, to the movable rigid conductor 301. When, in this state, a high current such as a short-circuit current flows through the circuit, the operating mechanism 4 operates to separate the movable-side contact 302 from the stationary-side contact 202. At this time, an arc A appears across the gap between the stationary-side contact 202 and the movable-side contact 302. As explained in detail hereinbelow with reference to Figure 4, in this arc A the metal particles are reflected by the arc shields 8 and 9, and the voltage in the arc space is thus made high, with the result that the arc is effectively cooled and extinguished.

Figure 4 is a model diagram showing the behaviour of the metal particles in the circuit breaker of Figures 3(a) and 3(b). The metal particle behaviour to be described may also be regarded as being substantially identical in an instance where the surfaces X are constructed of the contact material. In Figure 4, a pair of rigid conductors 6 and 7 are constructed in the same form as those of Figure 2, and the arc shields 8 and 9 respectively project beyond the surfaces X, the opposing surfaces of the respective rigid conductors 6 and 7, and are affixed to the respective rigid conductors 6 and 7. With this construction, the pressure values in the spaces Q cannot exceed the pressure value of the space of the arc A itself. However, much higher values are exhibited, at least in comparison with the values attained without the arc shields 8 and 9. Accordingly, the peripheral spaces Q which have the relatively high pressures caused by the arc shields 8 and 9 generate forces that suppress the spread of the space of the arc A and confine the arc A to a small area. This results in fining and confining into the arc space of the flow lines m, m', o and o' of metal particles a and c 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, large quantities of effectively injected metal particles a and c take large quantities of energy from the arc space, and the arc space is markedly cooled. Accordingly, the resistivity ρ, i.e. the arc resistance R, and hence the arc voltage, are greatly raised.

Further, when the arc shields 8 and 9 as shown, for example, in Figures 3(a) and 3(b) are disposed near and around the contact surfaces of the stationary-side contact 202 and the movable-side contact 302, namely the opposing surfaces X shown in Figure 4, the arc A is prevented from moving to the other surfaces Y of the rigid conductors, and also the size of the foot of the arc A is limited. Thus, the emission of metal particles a and c is concentrated on the surfaces X, and the arc sectional area S is contracted, so that the effective injection of the metal particles a and c into the arc space is further promoted. Accordingly, the cooling of the arc space, and the rise of the arc resistivity and of the arc resistance R are further improved, and the arc voltage can be further raised.

Next, Figures 5(a) and (b) to Figures 12(a) and (b) relate to various embodiments of a contactor of a circuit breaker according to the present invention. In Figures 5, 6, 7, 10, 11, 12 and 13, the illustration is restricted for simplicity to the stationary contactor side as exemplary of the embodiment as a whole. That is to say, the arc shield or contact on the movable contactor side in each embodied case may be regarded as being provided similarly and with a similar configuration to the corresponding stationary contactor side arc shield or contact, and so illustration is omitted.

Figures 5(a) and (b) illustrate an embodiment wherein the arc shield 8 and the contact 202 have substantially the same form in plan view, and they are respectively affixed to the rigid conductor 201 of the stationary contactor 2 such that their planar centers substantially coincide. Figure 5(a) is a plan view of the contact portion of the stationary contactor 2 of the embodiment, and Figure 5(b) is a side view of the same. In this embodiment, the plan form of the arc shield 8 affixed to the stationary rigid conductor 201 of the stationary contactor 2 is substantially the same as that of the stationary-side contact 202, and the planar centers of the arc shield 8 and the stationary-side contact 202 are arranged so as to substantially coincide. In the illustrated embodiment the contact and the arc shield each have a shape which in plan view is substantially trapezoidal. The forming of the contact and the arc shield such that they have similar plan forms, and positioning them such that their planar centers coincide, as described above, effectively confines the arc produced across the gap between the contacts during the tripping operation of the circuit breaker as shown in Figure 3(b). That is to say, the shape of the arc in the vicinity of the stationary-side contact 202 and the movable-side contact 302 in cross-section closely resembles the shape of those contacts 202 and 302. Further, the periphery of the arc is subject to an equal compressive force from the anode or cathode spots in the vicinity of the contacts, to the positive column in the center of the arc, by the arc shields 8 and 9 which are similar in plan form to the respective contacts 202 and 302, and so efficient confining of the arc A is achieved from the moment that the arc is produced. Thus, the potential inclination of the anode and cathode and the positive column can be effectively raised from the moment of arc generation, and the arc voltage between the contacts can be further increased.

In the embodiment shown in Figures 5(a) and (b), the stationary-side contact 202 and the arc shield 8 are shown as having a trapezoidal shape in plan view, but, of course, the may have any suitable shape, such as round, rectangular, elliptical, polygonal, etc. Further, in a case where the rated current is 100 A, the dimensions of the stationary contactor 2 of Figures 5(a) and 5(b) are fundamentally the same as the corresponding dimensions in the embodiment of Figures 3(a) and 3(b),but the stationary-side contact 202 is a trapezoid of parallel sides of 3 mm and 6 mm length, and of a height of 5 mm. The height of the contact 202 itself is 3,5 mm, and the lower surface of the contact 202 is affixed to the upper surface of the stationary rigid conductor 201. The arc shield 8 is 2 mm thick, and is formed as a trapezoid in plan view, with parallel sides of 9 mm and 20 mm length and a height of 20 mm. Centrally of the arc shield 8 is provided a through-hole of trapezoidal plan, substantially corresponding in size and shape to the stationary-side contact 202 which projects therethrough.

Figures 6(a) and 6(b) illustrate an embodiment wherein the contact 202 is rectangular in plan and the arc shield 8 is circular in plan. Figure 6(a) is a plan view of the contact portion of the stationary contactor 2 of the embodiment, and Figure 6(b) is a side view of the same. At the moment of the tripping operation of the circuit breaker, the peripheral shape of the arc A produced between the stationary-side contact 202 and the movable-side contact 302 as shown in Figure 3(b), in the vicinity of the rectangular stationary-side contact 202 and the movable-side contact 302, is rectangular, closely resembling the shape of the contacts 202 and 302. However, as the arc A advances to the central point between the contacts, the sectional shape of the arc A is made circular by the pinch effect of the arc A itself.

Accordingly, with the arc shields 8 and 9 round in plan, the round portion of the section of the arc A, i.e. the outer periphery of the central portion of the arc positive column, is evenly subjected to a confining force as hereinabove described, and the potential inclination of the positive column is effectively raised, while the arc voltage between the contacts is further increased.

For a circuit breaker of 100 A rating, the dimensions of this embodiment, with the exception of the arc shields 8 and 9, are the same as the dimensions of corresponding portions in the embodiment of Figures 3(a) and 3(b). The arc shield 8 is 2 mm thick, and is circular in plan with a 25 mm diameter, and a rectangular through-hole is provided centrally thereof with a shape and size substantially corresponding to the stationary-side contact 202 which projects therethrough.

Figures 7(a) and 7(b) illustrate an embodiment wherein the contact 202 is circular in plan and the arc shield 8 is rectangular in plan. Figure 7(a) is a plan view of the contact portion of the stationary contactor 2 of the embodiment, and Figure 6(b) is a side view of the same. At the moment of the tripping operation of the circuit breaker, the peripheral shape of the arc A produced between the stationary-side contact 202 and the movable-side contact 302 as shown in Figure 3(b), in the vicinity of the circular stationary-side contact 202 and movable-side contact 302, is circular, closely resembling the shape of the contacts 202 and 302. However, as the arc A advances to the central point between the contacts, the influence of the shape of the rectangular plan arc shields 8 and 9 makes itself strongly felt. That is to say,as illustrated in Figure 4, the distribution in the space Q, in which the pressure rises, corresponds to the shape of the arc shields 8 and 9, and the sectional shape of the arc A midway between the contacts accords to that pressure distribution, as shown in Figure 8. The thus deformed arc A, and particularly those portions of the arc A not within a cylinder defined between the faces of the opposing contacts 202 and 302, are strongly affected by the pinch force of the arc A itself, and so the arc A further contracts. Thus, the potential inclination of the positive column is effectively raised, and the arc voltage between the contacts is further increased.

For a circuit breaker of 100 A rating, the dimensions of this embodiment are basically the same as the corresponding dimensions in the embodiment of Figures 3(a) and 3(b), except that the stationary-side contact 202 is of circular plan with a 6 mm diameter. The height of the contact is 3,5 mm. The arc shield 8 is rectangular in plan, being 20 mm wide and 25 mm long, and has a plate-like configuration. The arc shield 8 is 2 mm thick. A circular through-hole is provided centrally of the arc shield 8 with a shape and size substantially corresponding to the stationary-side contact 202 which projects therethrough.

Figures 9(a), 9(b), 9(c) and 9(d) illustrate an embodiment wherein the stationary contactor 2 and the movable contactor 3 have the planar center points of their respective arc shields 8 and 9 located further from the arc-extinguishing plate assembly than the respective planar center points of the contacts 202 and 302. Figure 9(a) is a plan view of the contact portion of a stationary contactor of this embodiment, and Figure 9(b) is a side view of the same. Figure 9(c) is a plan view of the contact portion of a movable contactor of this embodiment, and Figure 9(d) is a side view of the same. In these figures, the arc shield 8 affixed to the rigid conductor 201 of the stationary contactor 2 has its planar central point located more remote from the arc-extinguishing plate assembly than the planar central point of the stationary-side contact 202, and similarly the arc shield 9 on the side of the movable contactor 3 has its planar central point located more remote from the arc-extinguishing plate assembly than the planar central point of the movable-side contact 302. By virtue of this disposition, at the moment of the tripping operation of the circuit breaker, the pressure distribution of the arc A in the space between the stationary-side contact 202 and the movable-side contact 302 is weaker on the side of the exhaust port 101 and stronger on the opposite side. Accordingly, the arc A generated across the gap between the stationary-side contact 202 and the movable-side contact 302 is distorted towards the side of the arc-extinguishing plate assembly 5 and the exhaust port 101 in Figure 3(b), and cooling of the arc A by the arc-extinguishing plate assembly 5, or the exhausting of hot gas from the exhaust port 101 are carried out with good effect. Thus, the potential inclination of the positive column is effectively raised, and the arc voltage between the contacts is further increased.

For a circuit breaker of 100 A rating, the dimensions of this embodiment, apart from the arc shields 8 and 9, are substantially the same as the corresponding dimensions of the embodiment of Figures 3(a) and 3(b). The arc shields 8 and 9 are substantially square plates with a thickness of 2 mm and sides of 25 mm length. In a position disposed towards the exhaust port, each of the arc shields 8 and 9 is provided with a through-hole of dimensions and configuration substantially corresponding to the respective contacts 202 and 302 which respectively project therethrough.

Figures 10(a) and 10(b) illustrate an embodiment wherein the arc shield 8 is formed with a concave surface. Figure 10(a) is a plan view of the contact portion of a stationary contactor of this embodiment, and Figure 10(b) is a side view of the same. In this embodiment, the surface of the arc shield 8 is concave in form, and so when an arc A is produced between the stationary-side contact 202 and the movable-side contact 302 at the moment of the tripping operation of the circuit breaker, as shown in Figure 3(b) the arc A is even more strongly confined, and the cross-sectional diameter of the arc column becomes even smaller than in the case with a flat plate arc shield. Accordingly, the potential inclination of the anode and cathode and the positive column are effectively raised from the moment of generation of the arc A, and the arc voltage between the contacts can be further increased.

For a circuit breaker of 100 A rating, the dimensions of this embodiment are substantially the same as the corresponding dimensions of the embodiment of Figures 6(a) and 6(b), except that the arc shield 8 is provided substantially centrally on the surface which opposes the arc A, with a spherical concavity with a surface radius of curvature of approximately 50 mm, and the thickness of the arc shield 8 at its thinnest point, i.e. in the vicinity of the central point, is approximately 2 mm. The concave depression is formed substantially concentrically with the arc shield 8, but does not extend fully to the outer circumference of the latter, leaving a flat circular band of 3 mm width around the concave depression.

Figures 11(a) and 11(b) illustrate an embodiment wherein the arc shield 8 is formed with a convex surface. Figure 11(a) is a plan view of the contact portion of a stationary contactor of this embodiment, and Figure 11(b) is a side view of the same. In this embodiment, the surface of the arc shield 8 is convex in form, and so the force confining the arc A at the time of the tripping operation of the circuit breaker, as shown in Figure 3(b), is inferior in its positive column potential inclination raising power as compared to the concave arc shield shown in Figures 10(a) and 10(b), but it does have the advantage that even where repeated switching of the contact causes wear of the contacts, the arc shields themselves will not make physical contact.

For a circuit breaker of 100 A rating, the dimensions of this embodiment are substantially the same as the corresponding dimensions of the embodiment of Figures 6(a) and 6(b), except that the surface of the arc shield 8 which opposes the arc A is formed with a spherical convexity of a radius of curvature of approximately 50 mm. The convexity extends fully to the outer circumference of the circular arc shield 8, and the thickness of the arc shield 8 at its thickest point, i.e. in the vicinity of its central point, is approximately 2 mm.

Figures 12(a) and 12(b) illustrate an embodiment wherein the surface of the arc shield 8 has an inclination. Figure 12(a) is a plan view of the contact portion of a stationary contactor of this embodiment, and Figure 12(b) is a side view of the same. In this embodiment, the flat top surface of the arc shield 8 is inclined downwards in the direction in which the arc A bows towards the arc-extinguishing plate assembly, and so directionality is imparted to the force that confines the arc A at the time of the tripping operation of the circuit breaker, as shown in Figure 3(b), and the arc length, i.e. the length of the current path, tends to increase. In other words, at the moment of arc generation, the length of the arc grows orthogonally to the contact surfaces of the stationary-side contact 202 and the movable-side contact 302, and due to the spaces Q, as shown in Figure 4, produced by the arc shield 8 with an inclined surface, the length of the arc varies in a direction orthogonal to the arc shield 8. As a result, the length of the arc increases and the arc voltage between the contacts is further increased.

In this embodiment, the inclination of the surface of arc shield 8 is downwards in the direction in which the arc A bows towards the arc-extinguishing plate assembly, but whatever direction the arc is caused to bow, the inclination may follow it with similar effects with regard to extending the length of the arc.

For a circuit breaker of 100 A rating, the dimensions of the embodiment are substantially the same as the corresponding dimensions of the embodiment of Figures 3(a) and 3(b), except that the surface of the arc shield 8 which opposes the arc A is formed with an inclination downwards in the direction of the arc-extinguishing plate assembly or the exhaust port, whereby the thickness of the arc shield 8 decreases gradually and evenly from its thickest point, the edge farthest from the arc-extinguishing plate assembly or exhaust port, where it is substantially 3 mm thick, to its thinnest point, the edge nearest the arc-extinguishing plate assembly or exhaust port, where it is substantially 1 mm thick.

Figures 13(a) and 13(b) illustrate an embodiment wherein the width of the contact decreases as it approaches the circuit breaker's arc-extinguishing plate assembly or gas exhaust port. Figure 13(a) is a plan view of the contact portion of a stationary contactor of this embodiment, and Figure 13(b) is a side view of the same. In this embodiment, the arc A generated between the stationary-side contact 202 and the movable-side contact 302 during the tripping operation of the circuit breaker, as shown in Figure 3(b), is drawn by the arc-extinguishing plate assembly 5 which is made of a magnetic material, and it moves in the direction of the exhaust port 101 due to the flow of the arc A, which has a high pressure, and so as the arc A moves, the width of its foot on the contact narrows. Thus, in addition to the effects of the arc shields 8 and 9 described hereinabove, the arc voltage can be even further raised. In the above embodiment, the arc shield is circular in form, but as the cross-sectional shape of the arc column comes to resemble the shape of the stationary-side contact 202 and the movable-side contact 302, having the shape of the arc shields 8 and 9 resemble the shape of the stationary-side contact 202 and the movable-side contact 302 further raises the effectiveness.

For a circuit breaker of 100 A rating, the dimensions of this embodiment, apart from the contact 202, are substantially the same as the corresponding dimensions of the embodiment of Figures 6(a) and 6(b). The stationary-side contact 202 has a substantially triangular plan, the base of the triangle being 5 mm and the height of the triangle being 8 mm. The height of the contact is 3,5 mm, and the contact is affixed on its lower surface to the upper surface of the stationary rigid conductor 201. The arc shield 8 is a circular plate in form, 25 mm in diameter and 2 mm thick, and is provided at its central portion with a through-hole of a size and configuration substantially the same as the stationary-side contact 202 which projects therethrough.

Claims:

1. A circuit breaker comprising a pair of contactors (2, 3) comprising rigid conductors (201, 301) with contacts (202, 302) formed with a predetermined shape fastened thereto, said contactors (2, 3) functioning to open and close an electric circuit, and arc shields (8, 9) formed with a predetermined shape disposed on said contactors (2, 3), surrounding said contacts (202, 302) and covering and concealing therebehind said rigid conductors (201, 301) in the vicinity of said contacts (202, 302), and which substantially project beyond said rigid conductors (201, 301) in a direction traversing an arc struck across the gap between said pair of contacts (202, 302), and which has a resistivity higher than that of said rigid conductors (201, 301) of said contactors (2, 3).

2. A circuit breaker as claimed in claim 1, wherein said predetermined form of said arc shields (8, 9) fixed to said rigid conductors (201, 301) is substantially similar in plan to said predetermined form of said contacts (202, 302), and said arc shields (8, 9) are affixed to said rigid conductors (201, 301) such that their planar centers substantially coincide respectively with the planar centers of said contacts (202, 302).

3. A circuit breaker as claimed in claim 1, wherein said predetermined forms of said arc shields (8, 9) and said contacts (202, 302) are substantially different.

4. A circuit breaker as claimed in claim 1, wherein said contacts (202, 302) are rectangular in plan and said arc shields (8, 9) are circular in plan, and said arc shields (8, 9) are affixed to said rigid conductors (201, 301) such that their planar centers substantially

coincide respectively with the planar centers of said contacts (202, 302).

5. A circuit breaker as claimed in claim 1, wherein said contacts (202, 302) are circular in plan and said arc shields (8, 9) are rectangular in plan, and said arc shields (8, 9) are affixed to said rigid conductors (201, 301) such that their planar centers substantially coincide respectively with the planar centers of said contacts (202, 302).

6. A circuit breaker as claimed in claim 1, wherein said arc shields (8, 9) are affixed to said rigid conductors (201, 301) such that their planar centers are respectively disposed away from the planar centers of said contacts (202, 302) in a predetermined direction.

7. A circuit breaker as claimed in claim 1, wherein the surfaces of said arc shields (8, 9) surrounding said contacts (202, 302) are provided with a concavity.

8. A circuit breaker as claimed in claim 1, wherein the surfaces of said arc shields (8, 9) surrounding said contacts (202, 302) are provided with a convexity.

9. A circuit breaker as claimed in claim 1, wherein the surfaces of said arc shields (8, 9) surrounding said contacts (202, 302) are provided with an inclination in a predetermined direction.

10. A circuit breaker as claimed in claim 1, wherein the width of said contacts (202, 302) gradually narrows in a predetermined direction.

FIG. 1a

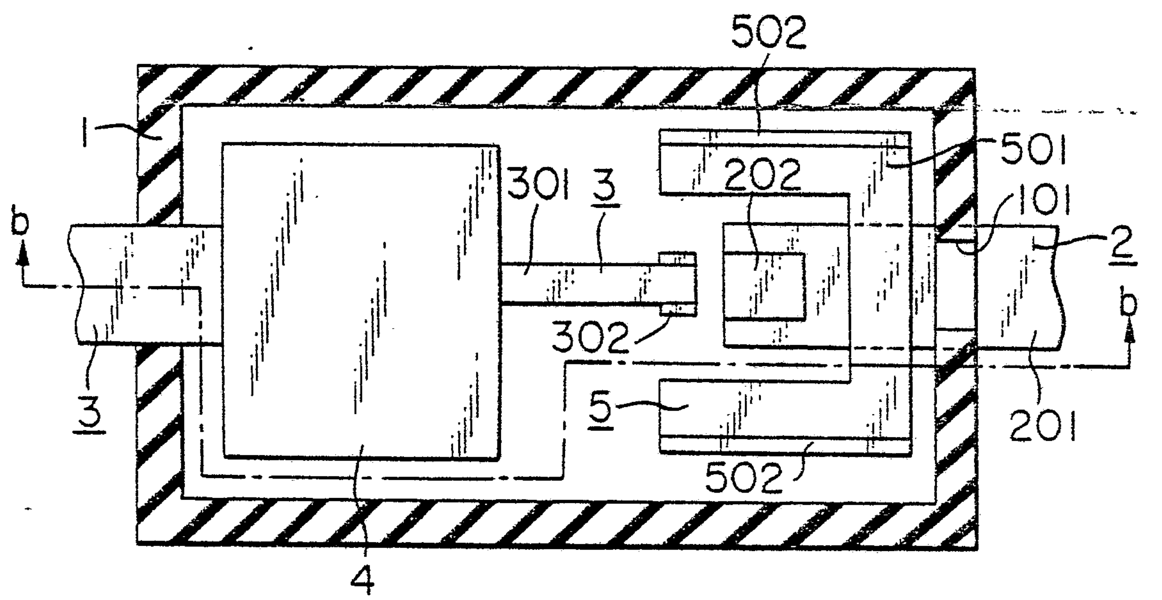
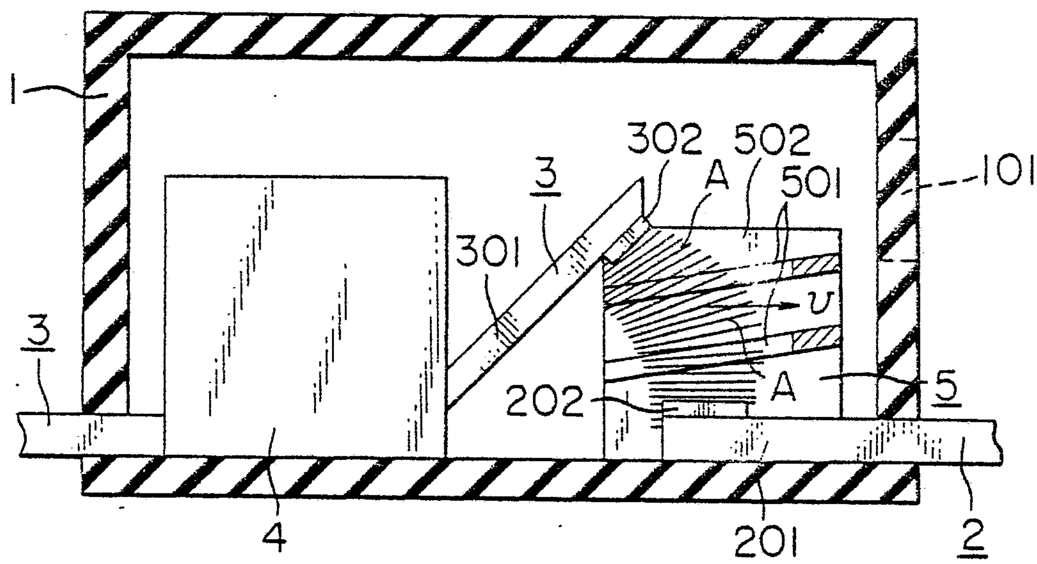


FIG. 1b



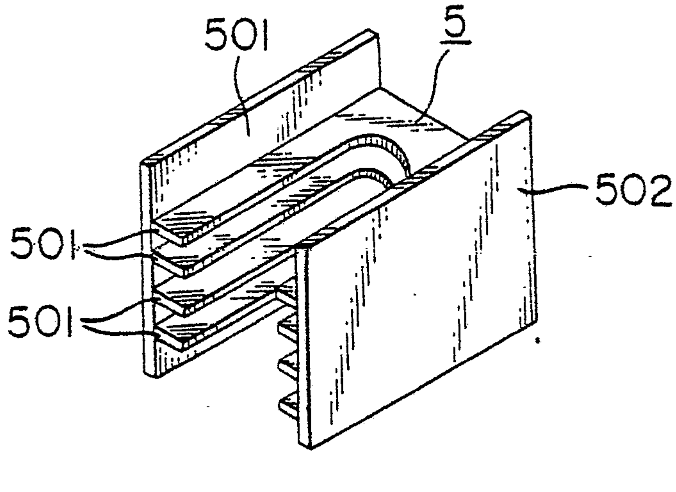


FIG. 1c

FIG. 2

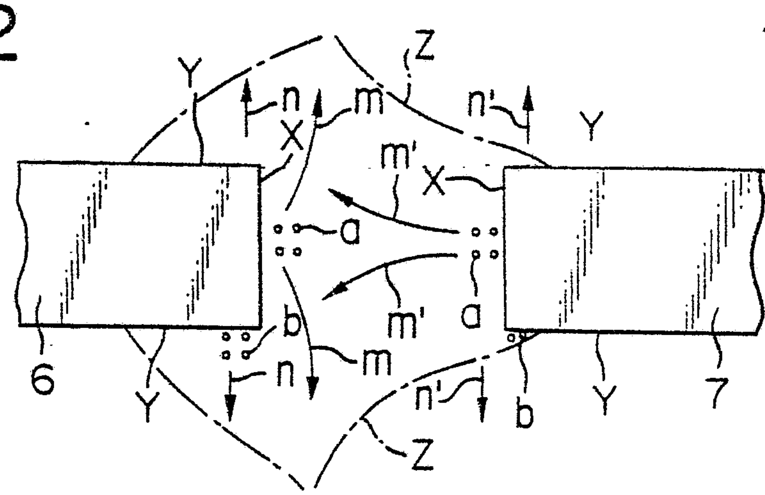


FIG. 3a

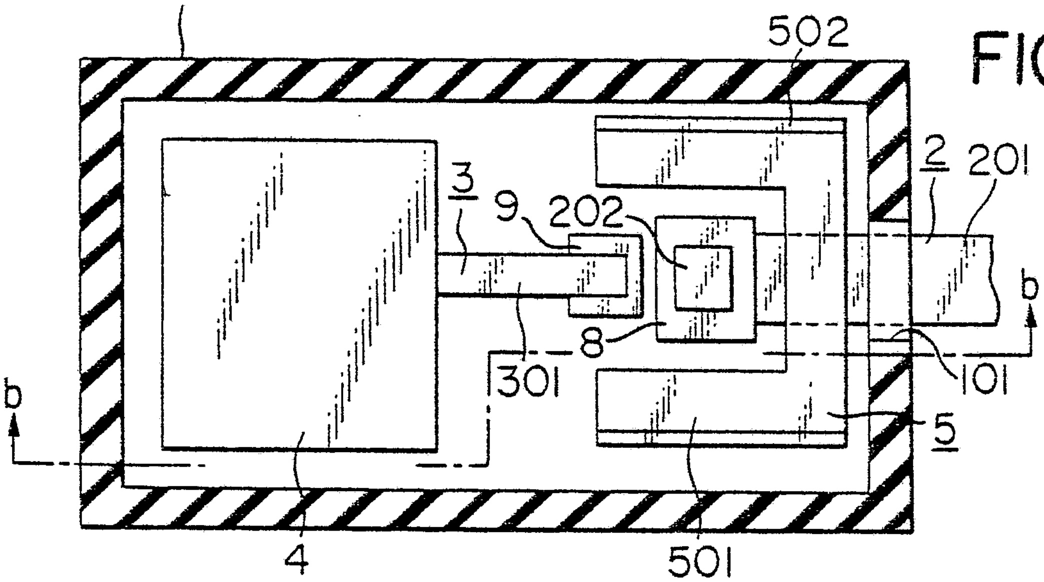


FIG. 3b

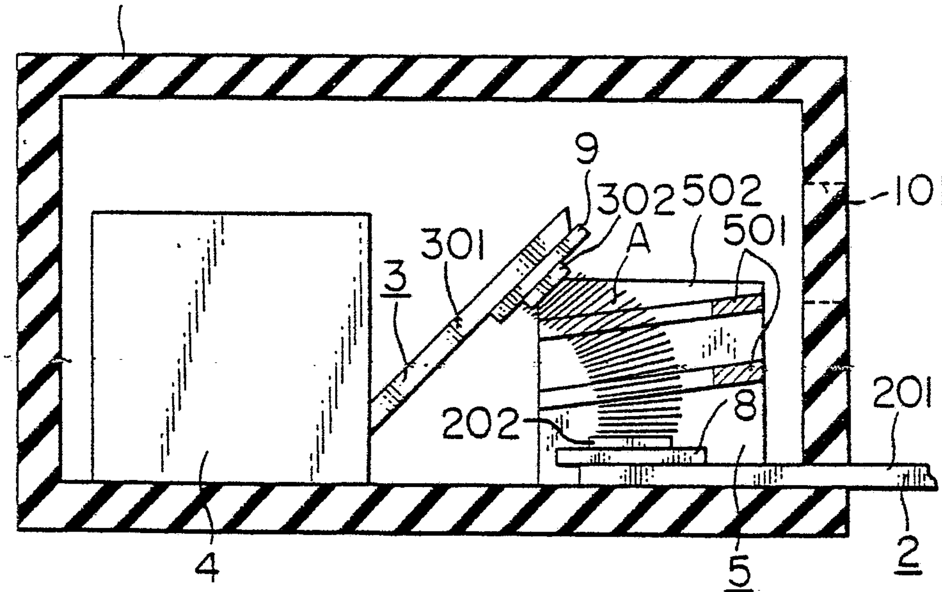
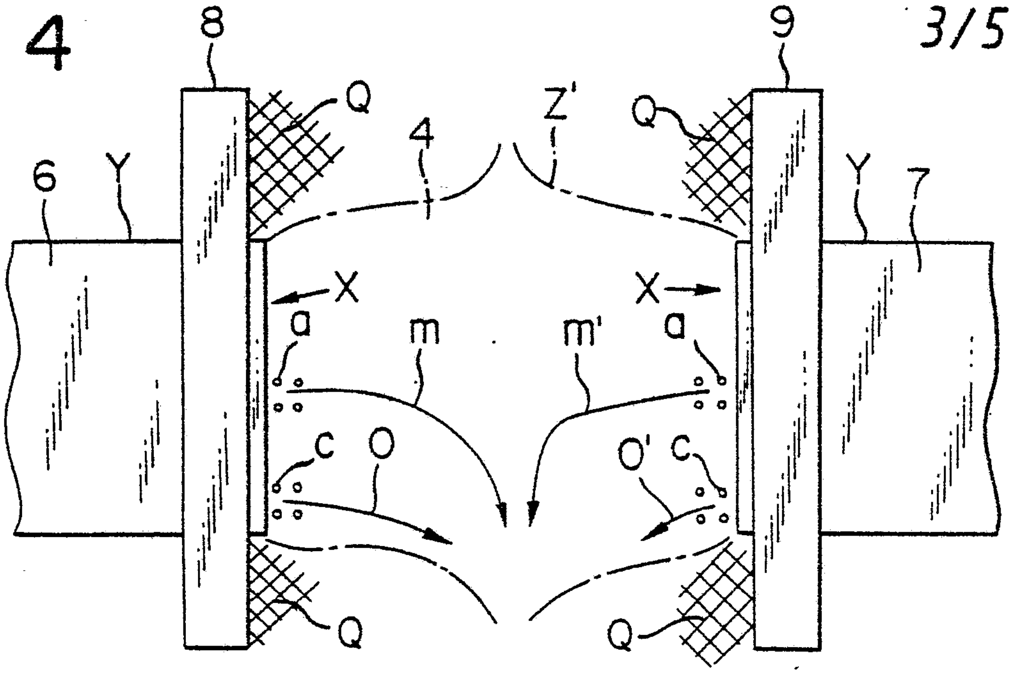


FIG. 4



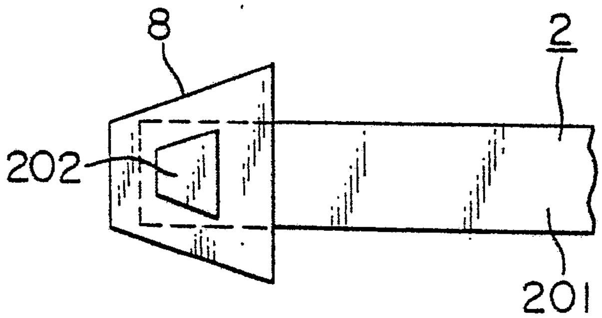


FIG. 5a

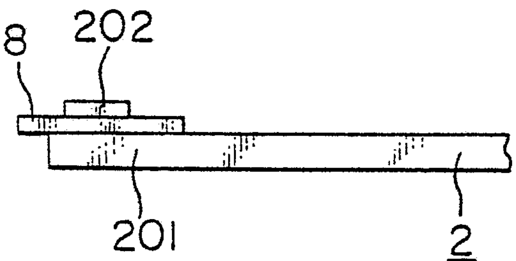


FIG. 5b

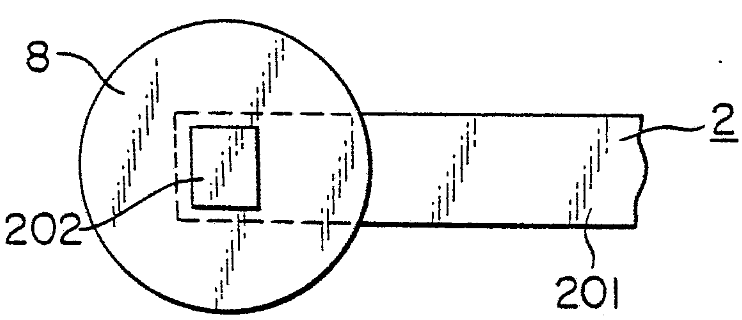


FIG. 6a

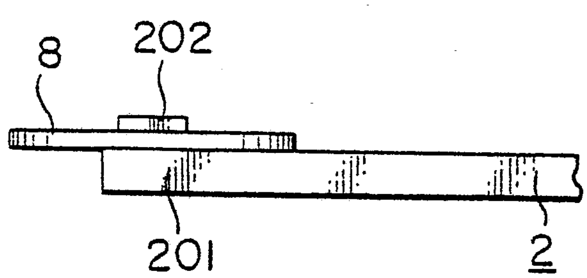


FIG. 6b

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FIG. 7a

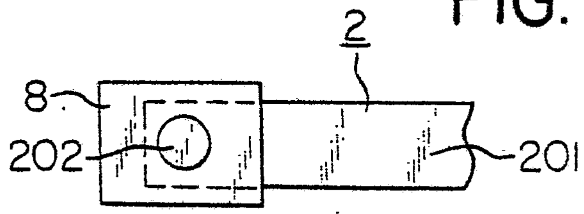
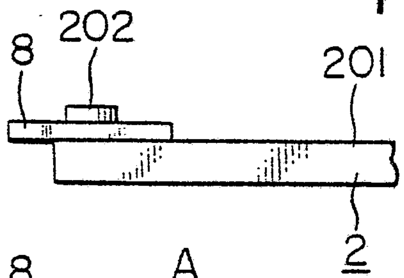


FIG. 7b



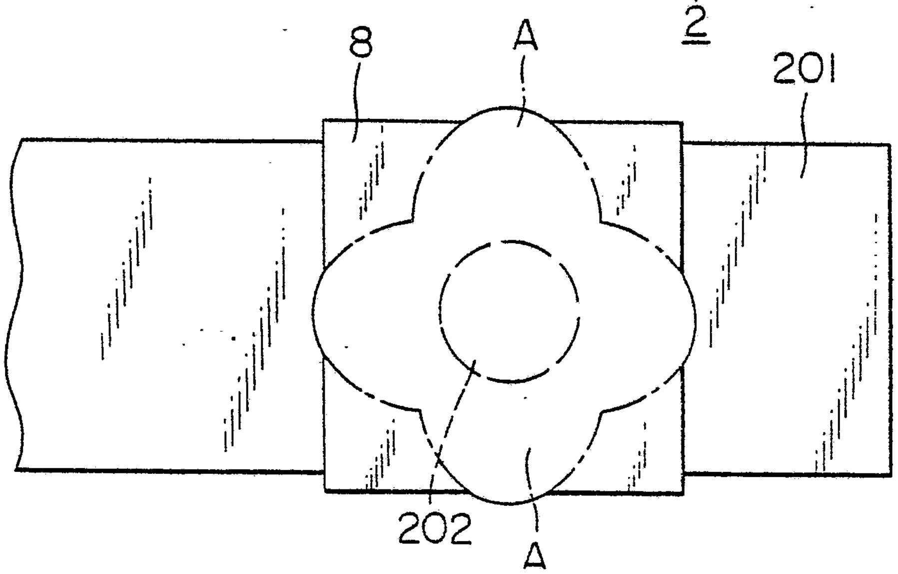


FIG. 8

FIG. 9a

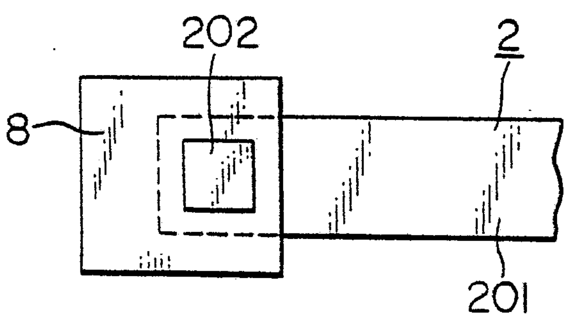


FIG. 9c

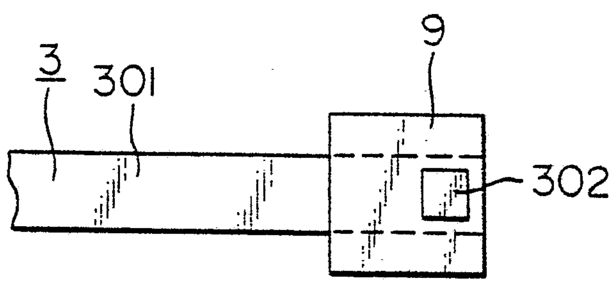


FIG. 9b

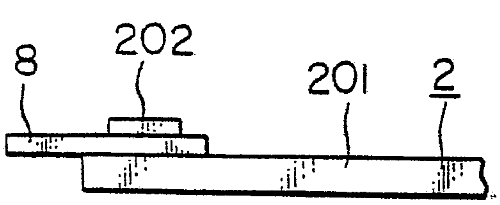


FIG. 9d

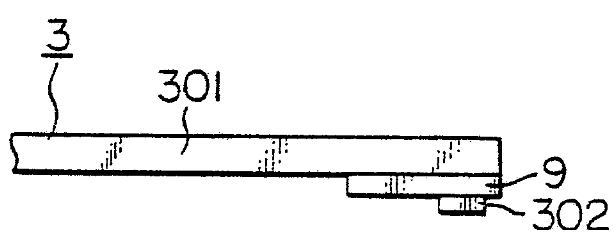


FIG. 10a

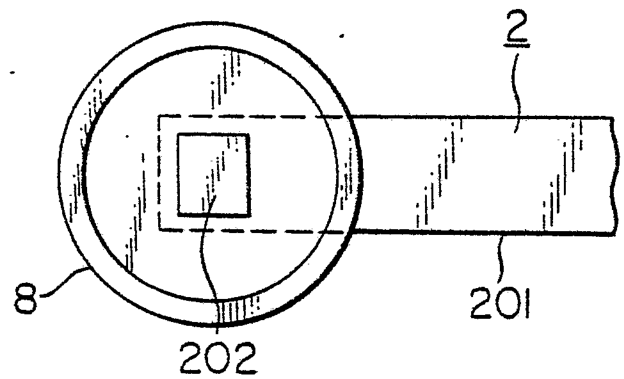


FIG. 10b

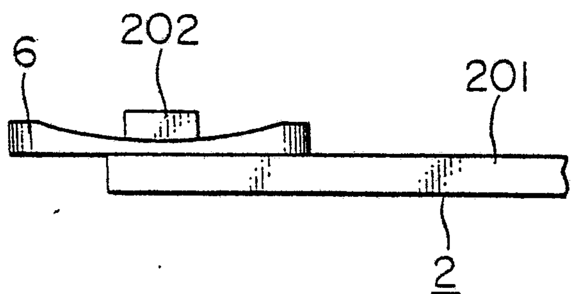


FIG. 11a

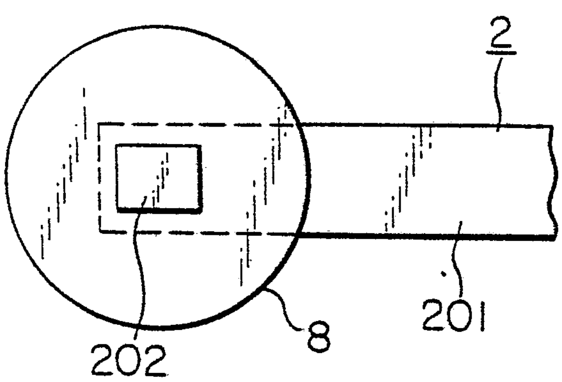


FIG. 11b

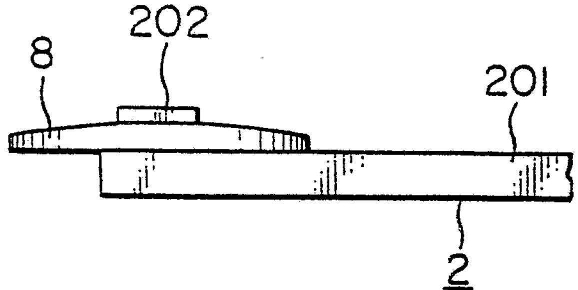


FIG. 12a

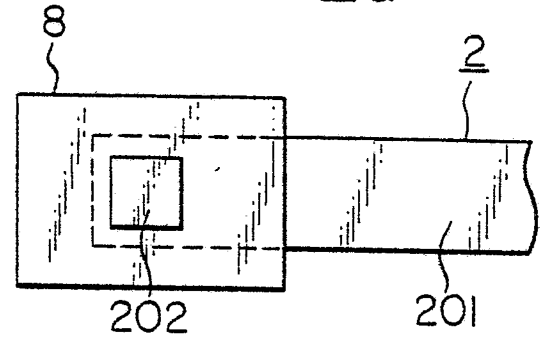


FIG. 12b

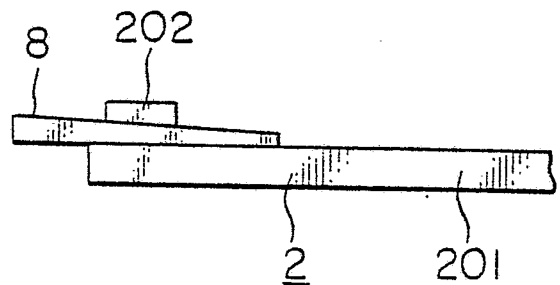


FIG. 13a

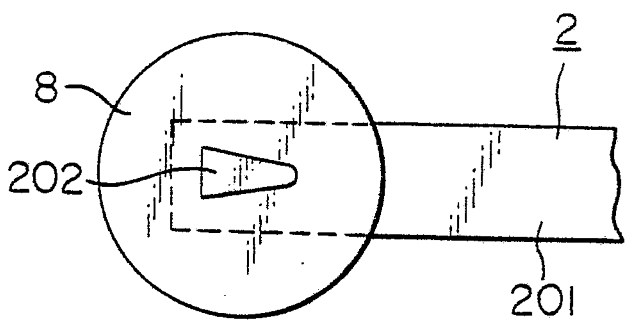


FIG. 13b