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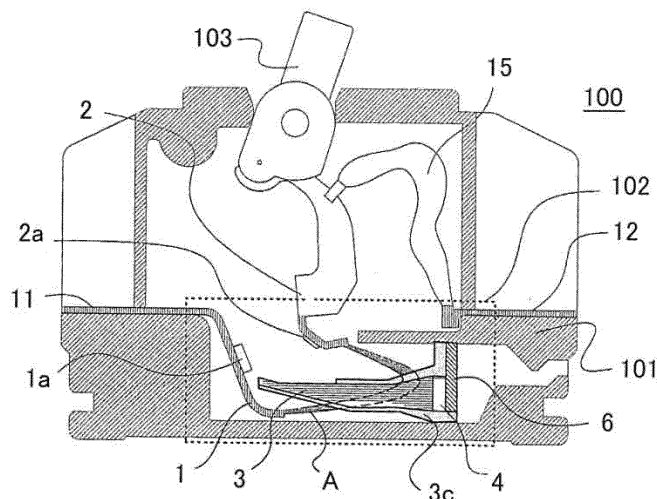
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(54) **SWITCHGEAR**

(57) A switchgear (100) is provided with a switch mechanism (103) that can connect or disconnect a movable contact (2a) to/from a fixed contact (1a); a magnet (4) that generates a magnetic field for extending an arc generated when the contacts (1a) and (2a) separate; and an elongated magnetic body (3), one end of which is in

contact with a magnetic pole face of the magnet. The other end of the magnetic body (3) is disposed near an arc-generating area between the fixed contactor (1) and the movable contactor (2), and the magnetic field generated by the magnet (4) extends the arc along a longitudinal side face of the magnetic body (3).

FIG. 1



## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to switchgears, such as switches, circuit breakers, electromagnetic contactors, and relays, which interrupt electric current.

### BACKGROUND ART

**[0002]** In a switchgear, an arc generated between its contacts is extended, thereby increasing the arc resistance, the arc voltage is raised high, and then current is interrupted. In particular, the technology to extend an arc is important because it is necessary, in a switchgear used for DC applications, to raise the arc voltage higher than the power source voltage and create a current-zero point so as to interrupt the current. In general, in order to extend an arc, magnetic flux lines from a permanent magnet are conventionally made to intersect the arc and the Lorentz force is made to act on the arc, whereby the arc is extended (see Patent Document 1, for example).

### PRIOR ART DOCUMENT

#### Patent Document

**[0003]** Patent Document 1: Japanese Laid-open Patent Publication JP 2009-087 918 A.

### DISCLOSURE OF THE INVENTION

#### Problem to be solved by the invention

**[0004]** In a switchgear equipped with a magnet in an arc-extinguishing chamber for extinguishing an arc, when the conduction direction is reversed, the arc-driven direction is also reversed, thereby causing a problem in that interruption reliability would be deteriorated. Moreover, although there have been proposed means in which an arc-extinguishing space is increased so as to interrupt current even if the arc is driven in the opposite direction, the problem has been that the means will increase the switchgear in size. Furthermore, not only magnetic drive force is difficult to act on an arc that has been driven and extended to outside a face facing a magnetic pole face of the magnet, but also magnetic field lines from the magnet generate electric magnetic force in unexpected directions, thereby deteriorating interruption reliability.

**[0005]** In a switchgear such as the above, magnetic field lines in a uniform direction, in order for a predetermined Lorentz force to act on the arc, need to act on a face on which the Lorentz force acts. In order to make the magnetic field lines in the uniform direction intersect the arc, a magnetic pole face of the permanent magnet needs to be widened larger than the foregoing face on which the Lorentz force acts, which will increase structural costs and as a result, will make it difficult to secure

its installation space.

**[0006]** Moreover, the magnetic field lines generated from the permanent magnet generate the Lorentz force in an unexpected direction to the arc located in a position that is not facing the magnetic pole face of the permanent magnet, thereby deteriorating interruption reliability, and in a worst-case scenario, causing an accident failing to interrupt the current. In a conventional switchgear equipped with a permanent magnet, the arc is in most cases extended to outside the face facing the permanent magnet; therefore, interruption reliability will be deteriorated in a switchgear such as described above.

**[0007]** Furthermore, a magnetic yoke is sometimes used in order to form the magnetic field lines from the permanent magnet also outside the face facing the permanent magnet; however, the Lorentz force generated by the magnetic field lines from the permanent magnet acts in the opposite direction if the current direction is changed. If the connection is reversed in this case, current interruption becomes difficult, thereby leading to an accident.

**[0008]** In order to avoid such an accident, it is necessary to provide a switchgear with an arc-extending space and a magnetic yoke that are large enough for the arc to extend even if the current direction is reversed and the arc is thereby moved in the opposite direction; therefore, a problem has been that the switchgear is increased in size.

**[0009]** The present invention has been made to resolve the foregoing problems, aiming at providing a switchgear that can secure sufficient interruption reliability, regardless of the current direction, even if a miniature magnet is used.

#### Means for solving the problem

**[0010]** A switchgear according to the present invention comprises a fixed contactor that has a fixed contact; a movable contactor that has a movable contact; a switch mechanism that opens and closes the fixed contact and the movable contact; and a magnet that extends in a controlled manner an arc generated between both contacts when the contacts are opened; wherein an attraction bar is provided, with one end portion of which disposed close to the arc-generating area and the other end portion thereof face-joined to one of the magnetic pole faces of the magnet.

#### Advantage of the invention

**[0011]** According to a switchgear of the present invention, the arc generated between the contactors can be driven, regardless of the current direction, toward the magnet along a side face of the attraction bar. At this moment, since the arc runs toward the magnet and is extended, while driven along the side face of the attraction bar, the arc is quickly cooled. Thus, a compact switchgear can be configured at low cost, while maintain-

ing high interruption reliability even if any reversed current flows.

# BRIEF DESCRIPTION OF THE DRAWINGS

## [0012]

FIG. 1 is a cross-sectional view schematically showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 1 of the present invention;

FIG. 2 is an explanatory view for explaining arc-extinguishing operation of the switchgear according to Embodiment 1 of the present invention;

FIG. 3 is a cross-sectional view showing various types of covers in an attraction bar portion of a switchgear according to Embodiment 2 of the present invention;

FIG. 4 is a cross-sectional view showing a variation of the various types of covers in the attraction bar portion of the switchgear according to Embodiment 2 of the present invention;

FIG. 5 is a side view showing another variation of an attraction bar portion of a switchgear according to Embodiment 3 of the present invention;

FIG. 6 is a side view showing still another variation of an attraction bar portion of a switchgear according to Embodiment 4 of the present invention;

FIG. 7 is a side view showing still another variation of an attraction bar portion of a switchgear according to Embodiment 5 of the present invention;

FIG. 8 is a side view showing still another variation of an attraction bar portion of a switchgear according to Embodiment 6 of the present invention;

FIG. 9 is a cross-sectional view showing still another variation of an attraction bar portion of a switchgear according to Embodiment 7 of the present invention, which is an application of Embodiment 4;

FIG. 10 is a side view showing a variation of a magnetic reinforcing plate of a switchgear according to Embodiment 8 of the present invention;

FIG. 11 is a cross-sectional view showing another variation of a magnetic reinforcing plate of a switchgear according to Embodiment 9 of the present invention;

FIG. 12 is a side view showing a layout example of a magnetic yoke and a magnetic yoke cover of a switchgear according to Embodiment 10 of the present invention;

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is a side view showing another layout example of a magnetic yoke and a magnetic yoke cover of a switchgear according to Embodiment 11 of the present invention, with the magnetic yoke and the magnet cover integrated into one piece;

is a side view showing a layout example of a magnetic guide plate and a magnetic guide plate cover of a switchgear according to Embodiment 12 of the present invention;

is a side view showing another layout example of a magnetic guide plate and a magnetic guide plate cover of a switchgear according to Embodiment 13 of the present invention;

is a cross-sectional view of FIG. 15 along the I - I line;

is a side view showing a layout example of a permanent magnet and an electromagnet of a switchgear according to Embodiment 14 of the present invention;

is a side view showing another layout example of a permanent magnet and an electromagnet of a switchgear according to Embodiment 15 of the present invention;

is a cross-sectional view schematically showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 16 of the present invention;

is a cross-sectional view of FIG. 19 along the II - II line;

is a side view showing the essential-part configuration of an arc-extinguishing chamber portion equipped with cooling plates made of an ablative resin material, of a switchgear according to Embodiment 17 of the present invention;

is a side view showing the essential-part configuration of an arc-extinguishing chamber portion equipped with cooling plates made of a metallic material, of the switchgear according to Embodiment 17 of the present invention;

is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 18 of the present invention;

is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 19 of the present invention;

is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear

according to Embodiment 20 of the present invention;

FIG. 26 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 21 of the present invention;

FIG. 27 is a plan view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 22 of the present invention;

FIG. 28A is a plan view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 23 of the present invention;

FIG. 28B is a plan view showing the essential-part configuration of an extinguishing chamber portion of a switchgear as a variation of Embodiment 23 of the present invention;

FIG. 28C is a plan view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear as another variation of Embodiment 23 of the present invention;

FIG. 29 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 24 of the present invention;

FIG. 30 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 25 of the present invention;

FIG. 31 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear according to Embodiment 26 of the present invention;

FIG. 32 is a cross-sectional view showing a variation of Embodiment 26 of the present invention;

FIG. 33 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 27 of the present invention;

FIG. 34 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion in the open state, of a switchgear according to Embodiment 28 of the present invention;

FIG. 35 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 29 of the present invention;

FIG. 36 is a cross-sectional view showing the es-

5 FIG. 37 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 30 of the present invention;

10 FIG. 38 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 31 of the present invention;

15 FIG. 39 is an explanatory view showing arc behavior inside the arc-extinguishing chamber viewed from a fixed-side terminal 11 in FIG. 38;

20 FIG. 40 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 32 of the present invention;

25 FIG. 41 is an explanatory view showing the essential-part configuration of an arc-extinguishing chamber portion viewed from the fixed-side terminal 11 in FIG. 40, which is a variation of Embodiment 33 of the present invention;

30 FIG. 42 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 34 of the present invention;

35 FIG. 43 is a cross-sectional view showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 35 of the present invention; and

40 FIG. 44 is oblique perspective views showing the essential-part configuration of an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 36 of the present invention; #

45 FIG. 44(a) is an oblique perspective view showing a state immediately after the switchgear is opened, and

FIG. 44(b) is an oblique perspective view showing a state of arcs joining together.

#### BEST MODE FOR CARRYING OUT THE INVENTION

**[0013]** Hereinafter, each embodiment of the present invention will be explained based on the drawings. Additionally, the same reference numerals represent the same or corresponding parts in each drawing.

### Embodiment 1.

**[0014]** FIG. 1 is a cross-sectional view showing the essential-part configuration of a switch mechanism, a relay unit, and an arc-extinguishing chamber portion of a switchgear in the open state, according to Embodiment 1 of the present invention; FIG. 2 is an explanatory view for explaining arc-extinguishing operation of the switchgear according to Embodiment 1 of the invention.

**[0015]** The switchgear 100 according to Embodiment 1 of the present invention comprises, as shown in FIG. 1, a fixed contactor 1 that has a fixed contact 1a; a movable contactor 2 that has a movable contact 2a; a switch mechanism 103 that opens and closes the fixed contact 1a and the movable contact 1b; a magnet 4 that generates a magnetic field for extending an arc generated between the fixed contactor 1 and the movable contactor 2 when the fixed contact 1a and the movable contact 2a are opened; and an elongated magnetic body 3 whose one end portion contacts a magnet pole face of the magnet 4; wherein the other end portion of the magnetic body 3 is disposed close to the arc-generating area between the fixed contactor 1 and the movable contactor 2.

**[0016]** The switchgear is basically made up of the magnet 4 that extends in a controlled manner the arc A generated between the fixed contactor 1 and the movable contactor 2 when the fixed contact 1a and the movable contact 2a are opened, and an attraction bar 3 that is the magnetic body, whose one end portion is disposed close to the arc-generating area and whose the other end portion is face-joined to one of the magnetic pole faces of the magnet 4, whereby the arc is extended along a longitudinal side face of the attraction bar 3, by the magnetic field the magnet 4 generates.

**[0017]** Hereinafter, the switchgear according to Embodiment 1 will be explained, referring to FIG. 1 and FIG. 2.

**[0018]** In FIG. 1, the switchgear 100 is provided with a fixed-side terminal 11 and a movable-side terminal 12, which are connected to an outside power circuit, at both end portions of a housing incorporating a case 101 made of an insulating material, and in a lower part thereof is provided an arc-extinguishing chamber 102 for extinguishing the arc.

**[0019]** In the arc-extinguishing chamber 102 are disposed the fixed contactor 1 that is integrally formed with the fixed-side terminal 11 and provided with the fixed contact 1a at its predetermined position; the movable contactor 2 that is provided with the movable contact 2a that contacts and/or separates from the fixed contact 1a and rotatably held; the attraction bar 3 that is made of the elongated magnetic body and whose one end portion is disposed close to the arc-generating area, facing a space sandwiched between the fixed contactor 1 and the movable contactor 2; and the magnet 4 that is adjoined (face-joined) to this attraction bar 3, with its magnetic pole face facing the end face of the other end portion of the attraction bar 3, that is, the end face of the other end

portion of the attraction bar 3 in the opposite side of the face facing the arc A generated between the fixed contact 1a and the movable contact 2a, being face-joined to this end face, and drives the arc along the peripheral side face of the attraction bar 3.

**[0020]** Additionally, the same effect can be produced even if the attraction bar 3 uses any shape, such as a round bar, a cuboid, a cylinder or a polygonal bar, and in addition, the attraction bar 3 is, as will be described later, protected by an insulating magnetic-body cover 3c that is provided facing the generating area of the arc A that has a conduction direction toward the front side of this paper face, and a magnetic reinforcing plate 6 described later is attached to the magnet 4. Other configurations and others not shown in the figure are the same as those using conventional technologies according to Patent Document 1, for example.

**[0021]** In the model shown in FIG. 2, the attraction bar 3 protected by the insulating magnetic-body cover 3c is disposed, and the end face of the attraction bar 3 in the opposite side of the arc-generating position is face-joined to the N-pole magnetic pole face of a permanent magnet 41; using this model, the principle of arc extinction will be explained next, with its progress until the arc extinction divided into 5 steps from step (I) to step (V).

**[0022]** First, in the arc-extinguishing progress step (I) in FIG. 2, magnetic field lines M generated by the permanent magnet 41 is guided by the attraction bar 3, so that a magnetic field intersecting the arc is generated in the direction from the tip of the attraction bar 3 toward the arc. The Lorentz force acts on the arc by the intersecting magnetic field, so as to drive the arc downward in FIG. 2.

**[0023]** Next, in the arc-extinguishing progress step (II), the magnetic field lines M that are formed as going around to the S-pole side of the permanent magnet 41 from the tip of the attraction bar 3 begin intersecting the arc that has been driven in the arc-extinguishing progress step (I). The arc is attracted by this intersecting magnetic field into an arc-extending space spreading over a longitudinal side face portion of the attraction bar.

**[0024]** Next, in the arc-extinguishing progress step (III), the arc attracted into the arc-extending space is further attracted into the back thereof by the magnetic field lines M generated along normal lines of the side face of the attraction bar 3. The more the arc is attracted into the back, the stronger the magnetic field generated from the side face of the attraction bar 3 becomes, so the arc becomes difficult to get away from the attraction bar 3; therefore, the arc can be stably extended toward the back (right side) of the attraction bar 3.

**[0025]** Moreover, the magnetic field lines intersecting the arc attracted into the back thereof include a number of magnetic field lines going around to the S-pole side of the permanent magnet 41, and the intersecting magnetic field generated by those magnetic field lines in this direction (right direction in the figure) generates force that drives the arc toward the inside of the attraction bar 3.

**[0026]** Next, in the arc-extinguishing progress step (IV), the Lorentz force to more strongly press the arc toward the inside of the attraction bar 3 comes to act on the arc near the insulating magnetic-body cover 3c that protects the attraction bar 3. Thereby, the arc is compressed against the insulating magnetic-body cover 3c, and the internal resistance of the arc is suddenly increased. Then, an ablation gas emitted by heat of the arc from the surface of the insulating magnetic body cover 3c exposed to the arc blows against the arc, whereby the arc is cooled, and which will further increase the internal resistance of the arc.

**[0027]** Last, in the arc-extinguishing progress step (V), when a recess 3e is made, as shown in the figure, in a portion of the insulating magnetic-body cover 3c, the arc is attracted into the recess by the Lorentz force pressing the arc toward the inside of the attraction bar 3, and the arc is thereby shrunk. Furthermore, the ablation gas by the insulating magnetic-body cover 3c blows against the shrunk arc from the periphery thereof, and the arc internal resistance is increased so high that the conductivity can no longer be maintained, thereby leading to the arc extinction.

**[0028]** Additionally, the foregoing configuration produces the same effect even if the conduction direction is reversed, and in each arc-extinguishing progress step, the arc is continuously extended, as shown in the figures, symmetrically with respect to the axis of the attraction bar 3. Moreover, even if the magnetic pole face of the permanent magnet 41 (or magnet 4) is reversed, the same effect can be produced, and the arc is continuously extended symmetrically with respect to the axis of the attraction bar 3.

**[0029]** By using the attraction bar 3 and the permanent magnet 41 (or magnet 4) as described above, the arc can be driven and extended in the same direction, so that interruption reliability can be enhanced without increasing the switchgear in size.

**[0030]** Furthermore, this Embodiment 1 produces further effects by adding the following parts to the basic configuration described above:

First, the switchgear is equipped with an arc-extending space portion; therefore, if the permanent magnet 41 (or magnet 4) is disposed in the arc-extending space portion, the arc extension length can be increased, so that the arc resistance can be further increased.

**[0031]** In addition, by providing the magnetic reinforcing plate 6, which is made of a magnetic material, on the magnetic pole face in the opposite side (opposite side of the attraction bar) of the permanent magnet 41 (or magnet 4) face adjoining (face-joining) the attraction bar 3, the magnetic resistance of a magnetic circuit formed by the magnetic field lines circulating in the periphery of the permanent magnet 41 (or magnet 4) is decreased, whereby the magnetic field generated from the attraction

bar 3 surface is increased in strength, so that arc-extinguishing capability can be further enhanced.

**[0032]** Furthermore, by configuring the magnet 4 used for Embodiment in FIG. 1 using the permanent magnet 41, a certain amount of magnetic flux can be made to act on the arc; therefore, stable interruption can be performed even in a current region where magnetic flux generated from an energizing conductor is weak (less than 1 kA, for example).

**[0033]** In addition, the permanent magnet 41 is used as the magnet used in the foregoing explanation of the arc extinction principle; however, as will be described later in Embodiments 14 and 15, the arc can be extinguished through the same phenomenon described above, even if a coil-shaped conductor that is electrically connected to either any one of the contactors or an outside power source is wound around part of the attraction bar 3 and the part of the attraction bar 3 is configured as an electromagnet 5.

**[0034]** The current range where a maximum effect can be exerted differs between when the permanent magnet 41 is used for the magnet and when the electromagnet 5 is used therefor; when the permanent magnet 41 is used, the effect is exerted in a relatively weak-current region (less than 1 kA, for example), whereas when the electromagnet 5 is used, the effect is pronounced in a relatively large-current region where the magnetic flux generated from a current flowing through the conductor becomes large (more than 1 kA, for example).

**[0035]** According to Embodiment 1 of the present invention as described above, adopting the foregoing basic configuration enables the generated arc A to be attracted into the back of the attraction bar 3 regardless of the conduction direction and extended, and following that, the arc is cooled and then extinguished.

#### Embodiment 2.

**[0036]** As shown in FIG. 1 and FIG. 2, the attraction bar 3, the magnet 4, and the magnetic reinforcing plate 6 are integrally molded in Embodiment 1 so that each can be protected from the arc; however, those parts in Embodiment 2 are provided with their respective insulating covers to protect each part as shown in FIG. 3 and FIG. 4, that is, an insulating magnetic-body cover 3c, a magnet cover 4c, a magnetic reinforcing plate cover 6c, a magnetic yoke cover 7c described later, and a magnetic guide plate cover 8c also described later are provided.

**[0037]** Next, Embodiment 2 will be explained based on FIG. 3 and FIG. 4, which is a variation of Embodiment 1 and provided with the insulating magnetic-body cover 3c that protects the attraction bar 3, the magnet cover 4c that protects the magnet, and the magnetic reinforcing plate cover 6c.

**[0038]** The insulating magnetic-body cover 3c, which is a protective insulating cover, and the magnet cover 4c are provided as shown in FIG. 3 and FIG. 4 in the periphery of the attraction bar 3 and the permanent magnet

41. Thereby, an effect of compressing and cooling the arc can be produced and interruption reliability can be further enhanced.

[0039] In addition, by providing the magnetic reinforcing plate 6 with the magnetic reinforcing plate cover 6c, the magnetic reinforcing plate 6 can be prevented from melting down by heat of the arc attracted into the proximity of the magnet, or the heat can be prevented from transmitting to the permanent magnet 41 via the magnetic reinforcing plate 6.

[0040] Furthermore, the arc is compressed and cooled by the magnetic reinforcing plate cover 6c, so that interruption reliability can also be enhanced.

[0041] Moreover, at least any one of the insulating magnetic-body cover 3c, the magnet cover 4c, the magnetic reinforcing plate cover 6c, and the magnetic guide plate cover 8c described later is formed of an ablative resin material, whereby the cooling effect by the ablation gas that blows against the arc A from the insulating magnetic-body cover 3c can be further enhanced, so that interruption reliability can be enhanced.

[0042] Furthermore, by providing the insulating magnetic-body cover 3c on the attraction bar 3 surface exposed to the arc as shown in FIG. 3, the cooling of the arc is expedited by the ablation gas, from the side face of the extended arc.

[0043] Furthermore, by providing a recess or a projection (uneven portion 3d) in part of the insulating magnetic-body cover 3c as shown in FIG. 3, the area of the insulating magnetic-body cover 3c contacting the arc that is pressed against the insulating magnetic-body cover is increased, so that the effect of cooling the arc by the ablation gas can be enhanced and interruption reliability can be further enhanced.

[0044] Furthermore, in the arc-extinguishing progress step (IV), the extended arc is pressed against the insulating magnetic-body cover 3c, so wear of the insulating magnetic-body cover 3c becomes significant at that point.

[0045] Therefore, the thickness 3cc of the insulating magnetic-body cover is increased as shown in FIG. 4 near the contacting face between the attraction bar 3 and the permanent magnet 41, whereby durability of the cover can be enhanced and interruption reliability can be further enhanced.

[0046] According to this FIG. 4, the effect of cooling the arc by the ablation gas from the insulating magnetic-body cover 3c or the magnet cover 4c can be effectively and continuously exerted.

[0047] Furthermore, by providing the magnet cover 4c, not only the arc A attracted into the side face portion of the permanent magnet 41 can be compressed and cooled, but also the permanent magnet 41 can be prevented from thermally degaussing by the heat of the arc.

[0048] Furthermore, even when a material with a high melting point is used, in order to enhance durability of the magnet cover 4c, for the arc in the arc-extinguishing progress steps until step (V), by providing recesses or

projections (uneven portion 4d) in part of the magnet cover 4c as shown in FIG. 4, the arc is attracted into the recesses of the uneven portion 4d of the magnet cover 4c, so as to increase the area of the magnet cover 4c contacting the arc, whereby the effect of cooling the arc can be enhanced. Therefore, the cooling of the arc can be expedited, while maintaining high durability of the magnet cover 4c.

[0049] Furthermore, by configuring the magnet 4 used in FIG. 1 with the permanent magnet 41 in FIG. 4, a certain amount of magnetic flux can act on the arc; therefore, stable interruption can be performed even in a current region where magnetic flux generated from an energizing conductor is weak (less than 1 kA, for example).

[0050] Furthermore, if the material with a high melting point is used for the magnet cover 4c that needs to prevent the permanent magnet 41 from thermally degaussing by the heat of the arc, and if at least any one of the insulating magnetic-body cover 3c, the magnet cover 4c, the magnetic reinforcing plate cover 6c, and the magnetic guide plate cover 8c described later is made of a material with a melting point lower than that of the magnet cover 4c, the arc A can be effectively cooled, while protecting the permanent magnet 41.

[0051] Furthermore, if at least any two of the insulating magnetic-body cover 3c, the magnet cover 4c, the magnetic reinforcing plate cover 6c, and the magnetic guide plate cover 8c described later are paired and integrally molded, the number of parts can be decreased and manufacturing costs can also be reduced.

[0052] As described above, according to Embodiment 2, an effect can be produced for each cover without providing all of the various kinds of covers, and effects can be added if the various kinds of covers are used together at the same time.

[0053] In addition, when various kinds of insulating covers are used, materials therefor can be selectively changed cover by cover.

### Embodiment 3.

[0054] Next, Embodiment 3 will be explained based on FIG. 5, which is a variation of the attraction bar 3, aiming at increasing the magnetic field strength of the magnetic field lines M formed from the attraction bar 3 toward the arc. Additionally, only the configuration including the attraction bar 3 and the permanent magnet 41 is explained in FIG. 5.

[0055] First, in the attraction bar 3 according to Embodiment 3 shown in FIG. 5, the area of the adjoining face (contacting face) between the attraction bar 3 and the permanent magnet 41 is made wider than the average cross-sectional area of the attraction bar 3.

[0056] According to this Embodiment 3, majority of the magnetic field lines M generated from a magnetic pole face of the permanent magnet 41 can be guided to inside the attraction bar, so that the density of magnetic flux intersecting the arc via the attraction bar 3 can be in-

creased, and the arc can be quickly attracted into the back of the attraction bar 3.

#### Embodiment 4.

**[0057]** Next, Embodiment 4 will be explained based on FIG. 6, which is another variation of the attraction bar 3, aiming at increasing the magnetic field strength of the magnetic field lines M formed from the attraction bar 3 toward the arc. Additionally, only the configuration including the attraction bar 3 and the permanent magnet 41 is explained in FIG. 6.

**[0058]** In the attraction bar 3 according to Embodiment 4 shown in FIG. 6, the area of the end face of the attraction bar 3 in the arc-generating space side is made smaller than the average cross-sectional area of the attraction bar 3.

**[0059]** That is to say, the magnetic field lines M distributed inside the attraction bar are concentrated at the tip of the attraction bar 3, the density of the magnetic flux generated from the tip of the attraction bar 3 is increased, and thereby the arc, not shown in the figure, located at the tip of the attraction bar 3 can be quickly attracted toward the attraction bar side.

#### Embodiment 5.

**[0060]** Next, Embodiment 5 will be explained based on FIG. 7, which is still another variation of the attraction bar 3, aiming at increasing the magnetic field strength of the magnetic field lines M formed from the attraction bar 3 toward the arc A. Additionally, only the main configuration including the attraction bar 3 and the permanent magnet 41 is shown in FIG. 7.

**[0061]** In the attraction bar 3 according to Embodiment 5 shown in FIG. 7, the normal of the end face of the attraction bar 3 in the arc-generating space side is slanted to the arc A-generating position side.

**[0062]** In other words, the magnetic field lines generated from the tip of the attraction bar 3 is directed close to the arc A-generating position, whereby the magnetic flux density for attracting the arc A toward the attraction bar side is increased; therefore, also the arc that is not generated on the extension of the axial line of the attraction bar 3 can be easily attracted.

#### Embodiment 6.

**[0063]** Embodiment 6 will be explained next based on FIG. 8, which is still another variation of the attraction bar 3, aiming at enhancing the magnetic field strength of the magnetic field lines M formed from the attraction bar 3 toward the arc A. Additionally, only the configuration including the attraction bar 3 and the permanent magnet 41 will be explained in FIG. 8.

**[0064]** The attraction bar 3 according to Embodiment 6 shown in FIG. 8 is an example of Embodiment 3 to Embodiment 5 being combined with each other. Each

embodiment is not only implemented by itself, but also implemented with those combined with each other, whereby effects of attracting the arc A toward the attraction bar can be added and exerted. An enhanced intersecting magnetic field is enabled to act even on the arc A, not shown in the figure, which is not on the extension of the axial line of the attraction bar 3, so that the arc can be easily attracted toward the attraction bar.

#### Embodiment 7.

**[0065]** Embodiment 7, which is still another variation of the attraction bar 3, will be explained based on FIG. 9 next. The attraction bar 3 according to Embodiment 7 shown in FIG. 9 is a variation of that of Embodiment 4; the insulating magnetic-body cover 3c is added to the attraction bar 3 and the permanent magnet 41 of Embodiment 4.

**[0066]** According to Embodiment 7, a magnetic field line configuration is formed in such a way that the magnetic field lines generated from a magnetic pole face of the permanent magnet 41 are concentrated at the tip of the attraction bar 3 and circulate from the tip of the attraction bar 3 to the other magnetic pole face of the permanent magnet. That is, the arc, not shown in the figure, which comes close to the tip of the attraction bar undergoes attracting force that presses the arc onto the insulating magnetic-body cover 3c by the circulating magnetic field lines M, and furthermore the ablation gas from the insulating magnetic-body cover 3c begins blowing against the compressed arc. Therefore, even when a space for extending the arc cannot be secured, an effect of extinguishing the arc can also be exerted, while saving the space by this Embodiment 7.

#### Embodiment 8.

**[0067]** Next, Embodiment 8 will be explained based on FIG. 10, which is a variation of the magnetic reinforcing plate of Embodiment 1, aiming at increasing the magnetic field strength of the magnetic field lines formed from the attraction bar 3 toward the arc A.

**[0068]** The magnetic reinforcing plate 6 according to Embodiment 8 shown in FIG. 10 is shaped to extend in a direction coming close to the arc-generating position.

**[0069]** According to Embodiment 8, the distribution of the magnetic field lines that has been formed symmetrically with respect to the center axis of the attraction bar 3 becomes biased, and the magnetic field lines are concentrated in a space in the arc A-generating position side. Therefore, the magnetic field made to act on the arc A can be increased in strength, so that the effect of attracting the arc A toward the attraction bar 3 can be enhanced.

#### Embodiment 9.

**[0070]** Embodiment 9, which is a variation of Embodiment 8, will be explained next based on FIG. 11.



**[0071]** The magnetic reinforcing plate 6 according to Embodiment 9 shown in FIG. 11 is extended in a direction coming close to the arc-generating position and furthermore the volume of magnetic reinforcing plate 6 is increased.

**[0072]** According to Embodiment 9, not only the magnetic field lines are concentrated in the space in the arc A-generating position side, but also the magnetic resistance of a magnetic circuit formed in the space in the arc A-generating position side is decreased, so that the magnetic field strength acting on the arc A can be enhanced.

#### Embodiment 10.

**[0073]** Next, Embodiment 10 will be explained based on FIG. 12, which is a variation of Embodiment 1, in which force that acts on the arc A located on the side face of the attraction bar and extends the arc toward the back of the attraction bar 3 is further increased, so as to enhance the cooling effect.

**[0074]** In Embodiment 10 shown in FIG. 12, a magnetic yoke 7 is disposed in such a way that part of the arc-extending space spreading over the side face of the attraction bar 3 is sandwiched by the attraction bar 3 and the magnetic yoke 7.

**[0075]** That is to say, the magnetic field lines M come to be concentrated from the attraction bar 3 toward the magnetic yoke 7, so that the Lorentz force that attracts the arc located on the side face of the attraction bar into the back of the attraction bar 3 is increased. Therefore, the arc can be quickly extended, and in addition, a strong compression effect can be produced by making the accelerated arc collide with the insulating magnetic-body cover 3c.

**[0076]** Moreover, by providing in FIG. 10 the magnetic yoke cover 7c on part of the magnetic yoke 7 surface exposed to the arc, the extended arc is sandwiched by the insulating magnetic-body cover 3c disposed on the side face of the attraction bar and the magnetic yoke cover 7c. In addition to an arc shrinking effect by restricting the space, a cooling effect can be produced by the ablation gas from both sides of both covers, so that the arc-extinguishing operation can be further enhanced.

**[0077]** Furthermore, the cooling effect can be exerted even when one of the covers is provided, so both covers are not necessarily required.

#### Embodiment 11.

**[0078]** Next, Embodiment 11, which is a variation of Embodiment 10, will be explained based on FIG. 13. The magnetic yoke 7 and the magnetic reinforcing plate 6 are integrated into one piece in Embodiment 11 shown in FIG. 13, and used as a combined part 67. Thereby, the magnetic resistance of a magnetic circuit formed in the periphery of the attraction bar is decreased, so that the Lorentz force acting on the arc located between the attraction bar 3 and the magnetic yoke 7 can be further

strengthened.

**[0079]** Therefore, by integrating the magnetic yoke 7 and the magnetic reinforcing plate 6, arc extension is further sped up without increasing the number of parts for the magnetic yoke 7, so that the arc A can be quickly extinguished.

#### Embodiment 12.

**[0080]** Next, Embodiment 12 will be explained based on FIG. 14, which is a variation of Embodiment 1, aiming at attracting the arc A generated at a position distant from the tip of the attraction bar 3.

**[0081]** In Embodiment 12 shown in FIG. 14, the position of the arc generated between the contactors is sandwiched by the tip portion of the attraction bar 3 and a magnetic guide plate 8 made of a magnetic material, and part of the magnetic guide plate 8 surface exposed to the arc is protected by the magnetic guide plate cover 8c.

**[0082]** According to Embodiment 12, the magnetic field lines generated from the tip of the attraction bar 3 can be drawn to the magnetic guide plate 8, so that the magnetic flux density in the space located between the tip of the attraction bar 3 and the magnetic guide plate 8 can be enhanced. Therefore, the Lorentz force to attract the arc toward the attraction bar 3 is enabled to act on the arc A distant from the attraction bar 3.

#### Embodiment 13.

**[0083]** Next, Embodiment 13, which is a variation of Embodiment 12, will be explained based on FIG. 15 and FIG. 16.

**[0084]** The magnetic guide plate 8 according to Embodiment 13 relates to the shape and a layout example of the magnetic guide plate 8; in the magnetic guide plate 8 according to Embodiment 13 shown in FIG. 15, at least part of the arc-generating space between the contactors is sandwiched by the magnetic guide plate 8 that is made of a magnetic material and at least part of whose surface exposed to the arc is protected using the magnetic guide plate cover 8c; and the attraction bar 3 is disposed in an arc-driven direction.

**[0085]** That is to say, the magnetic guide plate 8 not only guides the magnetic field lines generated from the tip of the attraction bar 3 to the arc-generating space sandwiched by the magnetic guide plate 8, but also guides magnetic field lines generated by a current flowing in both contactors, thereby facilitating attraction of the arc A toward the attraction bar 3. In addition, the magnetic guide plate 8 according to Embodiment 13 is formed in a U-shape as shown in FIG. 16; however, the same effect can be produced even if two or more plates and the like made of a magnetic material are disposed such that the arc-generating space is sandwiched therebetween.

#### Embodiment 14.

**[0086]** Next, Embodiment 14 will be explained based on FIG. 17, which is a variation of Embodiment 1 and uses the electromagnet 5 for the magnet 4.

**[0087]** Additionally, FIG. 17 illustrates only the essential-part configuration including the attraction bar 3, the permanent magnet 41, a first electromagnet (electromagnet in the attraction bar side) 5A, and the insulating magnetic-body cover 3c.

**[0088]** First, in FIG. 17, a coil-shaped conductor that is connected to either one of the fixed contactor 1 and the movable contactor 2 or the outside power source is wound round part of the periphery of the attraction bar 3 adjoining (face-joining) a magnetic pole face of the permanent magnet 41, that is, the other end portion of the attraction bar 3, and the part of the attraction bar 3 is configured as the electromagnet 5A.

**[0089]** That is to say, when interrupting a relatively small current, the arc A is attracted toward the attraction bar 3 by magnetic action by the permanent magnet 41, so as to be extinguished; meanwhile, when interrupting a relatively large current, a current proportional to the volume of current to be interrupted is made to flow through the electromagnet, and thereby the magnetic field generated by the permanent magnet 41 can be reinforced, so that the arc accompanied by a large current can be extinguished.

#### Embodiment 15.

**[0090]** Next, Embodiment 15, which is a variation of Embodiment 14, will be explained based on FIG. 18. In FIG. 18, in addition to the attraction bar 3 that has both the permanent magnet 41 and the first electromagnet 5A, a second electromagnet 5B that generates magnetic field lines in the opposite direction of those by the first electromagnet 5A (electromagnet in the opposite side of the attraction bar) is disposed on the magnetic pole face on which the attraction bar 3 is not adjoined (face-joined).

**[0091]** According to Embodiment 15, the magnetic field lines generated from the first electromagnet 5A toward the permanent magnet 41 can be cancelled out by those generated from the second electromagnet 5B, so that the influence of an outside magnet field attributed to the electromagnet 5A on the degaussing of the permanent magnet 41 can be prevented.

#### Embodiment 16.

**[0092]** Next, Embodiment 16 will be explained based on FIG. 19 and FIG. 20, which is a variation of Embodiment 1 and provided with cooling bars 9 disposed in a space in a side face portion of the attraction bar.

**[0093]** First, in the figure illustrating main constituent parts near the arc-extinguishing chamber, a plurality of cooling bars 9 are successively arranged in part of the arc-extending space spreading over the side face of the

attraction bar 3 so as to collide with the extended arc A.

**[0094]** According to this Embodiment 16, the arc A is extended by attracting action by the attraction bar 3, while colliding with the cooling bars 9, the cooling of the arc A progresses every time the arc collides, and then the arc A is extinguished after cooled.

**[0095]** Moreover, with the cooling bars 9 formed of a metallic material with high thermal conductivity, the heat of the arc A is quickly transmitted to the bars, so that the arc A can be easily deprived of its internal heat energy.

**[0096]** Furthermore, the cooling bars 9 may be formed of an ablative resin material. That is, an ablation gas is blown from the cooling bars 9 against the arc A that collides with the cooling bars 9, the cooling is expedited, and at the same time, the conductivity inside the arc can be lowered thanks to the physical property of the ablation gas. In particular, if a resin material including hydrogen is used, the thermal conductivity inside the arc is increased, so that the heat energy of the arc A can be easily dissipated.

#### Embodiment 17.

**[0097]** Next, Embodiment 17, which is a variation of Embodiment 16, will be explained based on FIG. 21 and FIG. 22.

**[0098]** In FIG. 21 and FIG. 22, a plurality of cooling plates 91 are successively arranged in part of the arc-extending space spreading over the side face of the attraction bar 3, along the axial direction of the attraction bar 3.

**[0099]** According to Embodiment 17, the same effect as that in Embodiment 16 can be produced; the cooling effect exerted on the arc A differs depending on which material is used for the cooling plates 91, an ablative resin or a metal.

**[0100]** That is to say, when the cooling plates 91 are made of an ablative resin material, the arc A is extended along the periphery of the cooling plates 91 as shown in FIG. 21, so that the arc length can be greatly increased, and in addition, the ablation gas is blown into the inside of the arc A at almost all portions thereof, so that the arc A can be easily cooled.

**[0101]** Meanwhile, when the cooling plates 91 are made of a metallic material, the arc A is, as shown in FIG. 22, divided (split) by the cooling plates 91, the divided arc A is cooled with its heat transmitted to the cooling plates 91, and in addition, a voltage drop occurs at the interface between the arc A and the cooling plates 91 due to an electrode-fall voltage, which will consequently act to reduce a current flowing inside the arc.

#### Embodiment 18.

**[0102]** Next, another embodiment of a switchgear using cooling plates formed in a different form from Embodiment 17 will be explained based on FIG. 23.

**[0103]** In FIG. 23, the fixed contact 1a is fixed to the

fixed contactor 1, and the movable contact 2a is fixed to one end portion of the movable contactor 2, and these contactors are paired with each other. One end portion of the fixed contactor 1 is electrically connected to a relay unit 104, for example, a bimetal that detects an overload current. Meanwhile, at the other end portion of the movable contactor 2 are provided a rotation axis (not shown in the figure) that rotatably holds the movable contactor 2 and the switch mechanism 103 that opens and closes the foregoing pair of contactors. In addition, a flexible conductor or a slide contactor is provided at the other end portion of the movable contactor 2 and electrically connected to a traveling electric path 111.

**[0104]** The fixed contactor 1 is extended from the end portion to be connected, via a bent portion, toward the side of the cooling plates 91 that are made of a metallic magnetic material and divide the arc A and cause a voltage drop inside the arc. Meanwhile, the traveling electric path 111 is once bent toward the fixed contactor 1 side, then again extended obliquely toward the bottom side of the housing (downward in FIG. 23), and one end portion of which is disposed under the cooling plates 91.

**[0105]** That is, the plurality of cooling plates 91 are arranged as vertically surrounded by the end portions of the fixed contactor 1 and the traveling electric path 111 in the cooling plates 91 side. This plurality of cooling plates 91 are held by cooling side plates at suitable intervals as sandwiched in the direction perpendicular to this paper face, and a necessary number of cooling plates 91 are secured so that a predetermined current limiting capability can be achieved.

**[0106]** These constituent parts of the switchgear are accommodated in the case 101 constituting the housing. In addition, a handle for manually operating the switch mechanism 103 is provided as protruding from the case 101.

**[0107]** The attraction bar 3 made of a magnetic material is disposed in a space surrounded by the traveling electric path 111, and the magnet 4 is disposed with one of the magnetic pole faces adjoined (face-joined) to the end face of the attraction bar 3 in the opposite side of the face facing the arc A. Therefore, the arc A generated there is quickly attracted into the back of the attraction bar 3, and can be easily made to collide with the cooling plates 91 and cooled, leading to its extinction.

**[0108]** Moreover, the magnet 4 used for Embodiment in FIG. 23 may be configured using the permanent magnet 41. When the magnet is configured using the permanent magnet 41, a certain amount of magnetic flux can be made to act on the arc A; therefore, stable interruption can be performed even in a region where magnetic flux generated from the energizing conductor is weak (less than 1 kA, for example).

**[0109]** Furthermore, the area of the end face of the attraction bar 3 in the side of the arc-generating space is made smaller than the average cross-sectional area of the attraction bar 3. Thereby, the magnetic field lines distributed inside the attraction bar are concentrated at

the tip of the attraction bar 3, the density of the magnetic flux generated from the tip of the attraction bar 3 is increased, so that the arc A, not shown in the figure, at the tip of the attraction bar 3 can be quickly attracted toward the attraction bar side.

**[0110]** In addition, the normal of the end face of the attraction bar 3 in the side of the arc-generating space is slanted to the side of an arc A-generating position. That is, the magnetic field generated from the tip of the attraction bar 3 is directed close to the arc A-generating position, whereby the magnetic flux density for attracting the arc A toward the attraction bar side is increased, so that the arc A that is not generated on the extension of the axial line of the attraction bar 3 can be easily attracted as well.

**[0111]** Moreover, by forming the cooling plates 91 using a metallic material with high thermal conductivity, heat of the arc A is quickly transmitted to the cooling plates 91, so the arc A can be easily deprived of the internal heat energy. Furthermore, when the cooling plates 91 are made of the metallic material, the arc A is, as shown in FIG. 23, divided by the cooling plates 91, the divided arc A is cooled with the heat transmitted to the cooling plates 91, and in addition, a voltage drop occurs at the interface between the arc A and the cooling plates 91 due to an electrode-fall voltage, which will consequently act to reduce a current flowing inside the arc.

#### Embodiment 19.

**[0112]** Next, Embodiment 19, which is a variation of Embodiment 18, will be explained based on FIG. 24. In FIG. 24, part of the fixed contactor in the side where the cooling plate is disposed is removed, and the attraction bar 3 is disposed in a position in the fixed contactor side (upper side in the figure).

**[0113]** Moreover, the cooling plates 91 are successively arranged along the axial direction of the attraction bar 3, in part of the arc-extending space spreading under the attraction bar 3. The arc A is extended by attracting action by the attraction bar 3, while colliding with the cooling plates 91, the cooling of the arc A progresses every time the arc collides, and the arc A is extinguished after cooled.

**[0114]** In addition, by forming the cooling plates 91 using a metallic material with high thermal conductivity, heat of the arc A is quickly transmitted to the cooling plates 91, so that the arc A can be easily deprived of the internal heat energy. Furthermore, when the cooling plates 91 are made of the metallic material, the arc is, as shown in FIG. 23, divided by the cooling plates 91, the divided arc A is cooled with the heat transmitted to the cooling plates 91, and also a voltage drop occurs at the interface between the arc A and the cooling plates 91 due to an electrode-fall voltage, which will consequently act to reduce a current flowing inside the arc.

Embodiment 20.

**[0115]** Next, Embodiment 20 will be explained based on FIG. 25, which is a variation of Embodiment 1 and can produce the effect of this invention without disposing the attraction bar.

**[0116]** The switchgear in FIG. 25 is provided with an arc-extending space for extending the arc generated between the fixed contactor 1 and the movable contactor 2 and a bar magnet 42 that generates a magnetic field for extending the arc; the longitudinal side face of the bar magnet 42 is protected by the magnet cover 4c, and one end portion of a magnetic pole face of the bar magnet 42 is disposed as coming close to the arc-generating position located between the fixed contactor 1 and the movable contactor 2. Therefore, the arc is extended by the magnetic field generated by the bar magnet 42, along the longitudinal side face of the bar magnet 42, and also winds around the bar magnet 42, so that the arc can be cooled by an ablation gas emitted from the magnet cover 4c and then extinguished. Furthermore, since a high permeance modulus can be secured by making the bar magnet 42 longer than a certain length, the bar magnet can be prevented from thermally degaussing.

**[0117]** Moreover, by providing in part of the magnet cover 4c of the bar magnet 42 the uneven portion 4d (recesses or projections) for attracting and compressing the arc, the arc can be compressed in the recesses of the magnet cover 4c, and in addition, the ablation gas emitted from the magnet cover 4c can be effectively blown against the arc, so that interruption capability can be enhanced.

Embodiment 21.

**[0118]** Next, Embodiment 21 will be explained based on FIG. 26, which is another variation of Embodiment 1 and can produce the effect of this invention without disposing the attraction bar.

**[0119]** Embodiment 21 in FIG. 26 is provided with an arc-extending space for extending the arc generated between a pair of contactors 1 and 2 and the permanent magnet 41 that generates a magnetic field for extending the arc; the permanent magnet 41 is disposed at an arc-extending edge of the arc-extending space, and an uneven insulating magnet cover 416c is provided on side faces other than the magnetic pole faces of the permanent magnet 41.

**[0120]** Therefore, the arc is attracted into a recess 416d of the magnet cover 416c by the magnetic field generated by the permanent magnet 41 and compressed, and in addition, efficiency of cooling the arc can be enhanced by an ablation gas emitted from the bar magnet cover 416c.

**[0121]** Furthermore, by using for the permanent magnet 41 a magnet capable of generating strong magnetic force, such as a neodymium magnet, the arc can be attracted into the recess 416d of the magnet protection

cover 416c even if the arc is in a distant position.

Embodiment 22.

**[0122]** An arc-extinguishing chamber of a switchgear according to Embodiment 22 will be explained based on FIG. 27.

**[0123]** Additionally, FIG. 27 is a plan view showing only main constituent parts of the arc-extinguishing chamber.

**[0124]** The arc-extinguishing chamber according to Embodiment 22 is divided into a plurality of compartments, which is an application to switchgears that have poles for two or more phases.

**[0125]** In FIG. 27, a pair of fixed contactor 1 and movable contactor (not shown in the figure) that are electrically connected to outside conductors is provided for each phase in the case 101 capable of accommodating constituent parts of arc-extinguishing chambers for two phases. End portions of two attraction bars 31 and 32, in order to control at the same time two arcs A generated between their respective pairs of contactors, are disposed close to arc-generating areas of the plurality of arcs generated between the contactors of the plurality of pairs; the other end portions of the attraction bars 31 and 32 are disposed contacting their respective magnetic pole faces of the permanent magnet 41 that is disposed in a separating wall of the case 101 separating the two-phase arc-extinguishing chambers from each other; and in the periphery of each of the attraction bars 31 and 32 is provided the insulating magnetic-body cover 3c.

**[0126]** Therefore, the two arcs can be attracted at the same time by the attraction bars 31 and 32 using only the permanent magnet 41, so that high interruption reliability can be secured by a small number of parts.

Embodiment 23.

**[0127]** Arc-extinguishing chambers of a switchgear according to Embodiment 23 will be explained based on FIG. 28A next.

**[0128]** The attraction bars 31 and 32 shown in FIG. 27 do not necessarily need to be adjoined (face-joined) to both magnetic pole faces of the permanent magnet 41, but the attraction bar 3 that is divided into two-forked sections as shown in FIG. 28 may be adjoined (face-joined) to one of the magnetic pole faces of the permanent magnet 41, and end portions of the two-forked attraction bar 3 may be extended to their respective arc-generating positions.

**[0129]** In addition, the permanent magnet 41 is disposed in the wall separating each phase or disposed astride the two phases in FIG. 27 and FIG. 28B; however the disposal is not limited this, but the permanent magnet 41 may be provided for one of the phases and only one of the attraction bars 31 and 32 may be extended up to the other phase.

**[0130]** Next, arc-extinguishing chambers of a switchgear, as a variation of Embodiment 23, will be explained

based on FIG. 28B.

**[0131]** The attraction bars 31, 32 and 3 shown in FIG. 27 and FIG. 28A do not necessarily need to be adjoined (face-joined) to a magnetic pole face of the permanent magnet 41, but the permanent magnet 41 is embedded inside the case as shown in FIG. 28B, and thereby an insulating resin material may be interposed between the permanent magnet 41 and the attraction bars 31 and 32.

**[0132]** By doing so, even if the insulating magnetic-body cover 3c is broken, a short-circuit current can be prevented from flowing between neighboring phases via the attraction bars 31 and 32 and the permanent magnet 41.

**[0133]** Furthermore, arc-extinguishing chambers of a switchgear, as another variation of Embodiment 23, will be explained based on FIG. 28C.

**[0134]** As the attraction bars 31, 32, and 3 shown in FIG. 27, FIG. 28A, and FIG. 28B, the length of the attraction bars does not need to be the same between both of the phases, but either the attraction bar 31 or 32 may be made shorter than the other.

**[0135]** Thereby, positions to which the arcs are extended differ between the phases; therefore, an influence of the magnetic field generated from the arc in the neighboring phase can be suppressed. Therefore, even under the condition of current increasing in which the influence of the magnetic field generated from the arc in the neighboring phase becomes strong, the effect of this invention can be effectively exerted.

**[0136]** Furthermore, timing of opening the contactors may be delayed in only the phase provided with the attraction bar 32 that is shorter than the other. Therefore, the arc generated in the phase of opening the contactors earlier is extended without undergoing the influence of the arc generated in the neighboring phase in which the timing of opening the contactors is delayed, so that fluctuation of interruption timing can be suppressed and stable interruption can be performed.

#### Embodiment 24.

**[0137]** Next, an arc-extinguishing chamber of a switchgear according to Embodiment 24 of the present invention will be explained based on FIG. 29.

**[0138]** The arc-extinguishing chamber of the switchgear according to this Embodiment 24 is an application in which a plurality of arc-extinguishing spaces are provided for one phase.

**[0139]** In FIG. 29, the permanent magnet 41, two arc-extinguishing spaces, and an electromagnetic actuator unit 105 are accommodated inside the case 101; in each arc-extinguishing space are provided the movable contactor 2 that has the movable contact 2a, the fixed contactor 1 that has the fixed contact 1a, and the attraction bar 3 that is protected by the insulating magnetic-body cover 3c, extended to between both contactors 1 and 2 from a magnetic pole face of the permanent magnet 41, and disposed close to an arc-generating area; and the

movable contactor 2 can be opened by operating an outside circuit not shown in the electromagnetic actuator unit 105.

**[0140]** Moreover, the area of the end face of the attraction bar 3 in the side of the arc-generating space is made smaller than the average cross-sectional area of the attraction bar 3. Thereby, magnetic field lines distributed inside the attraction bar are concentrated at the tip of the attraction bar 3, the density of magnetic flux generated from the tip of the attraction bar 3 is increased, so that the arc A, not shown in the figure, located at the tip of the attraction bar 3 can be quickly attracted toward the attraction bar side.

**[0141]** Furthermore, the normal of the end face of the attraction bar 3 in the side of the arc-generating space is slanted to the side of the arc A-generating position. That is, the magnetic field lines generated from the tip of the attraction bar 3 are directed close to the arc A-generating position, whereby the magnetic flux density for attracting the arc A toward the attraction bar side is increased, and the arc A that is not generated on the extension of the axial line of the attraction bar 3 can be easily attracted as well.

**[0142]** According to this Embodiment 24, the arc A generated between both contacts 1a and 2a of each of the two arc-extinguishing spaces is attracted into the back of the attraction bar 3 and extended, and following that, the arc is cooled by an ablation gas emitted from the insulating magnetic-body cover 3c, leading to its extinction. The permanent magnet 41 is disposed inside the case in FIG. 29; however, the disposal is not limited to this. For example, the permanent magnet 41 is disposed in one of the arc-extinguishing spaces and the attraction bar 3 may be extended up to the other arc-extinguishing space.

#### Embodiment 25.

**[0143]** Next, Embodiment 25, which is a variation of Embodiment 24, will be explained based on FIG. 30. As shown in FIG. 30, the permanent magnet 41 may be provided for each arc-extinguishing space.

**[0144]** According to this Embodiment 25, since magnetic field lines from the permanent magnet 41 can be formed for each arc-extinguishing space, an applicable current region can be expanded.

#### Embodiment 26.

**[0145]** Next, Embodiment 26, which is a variation of Embodiment 25, will be explained based on FIG. 31 and FIG. 32.

**[0146]** As shown in FIG. 31 and FIG. 32, the plurality of arc-extinguishing spaces do not necessarily need to be provided for one phase, but only a large arc-extinguishing space with the permanent magnet 41 and the attraction bar 3 may be provided instead.

**[0147]** According to this Embodiment 26, contacting

pressure to hold below a necessary amount of force contacting force generated between both contacts in the closed state and contact-opening force to open the contacts faster than a predetermined speed can be halved, so that the electromagnetic actuator unit 105 can be decreased in size.

**[0148]** Moreover, since a space large enough for extending the arc A can be secured, wear of the contacts by heat of the arc can be suppressed, so that contact reliability can be enhanced.

#### Embodiment 27.

**[0149]** A switchgear according to Embodiment 27 will be explained based on FIG. 33 next.

**[0150]** In FIG. 33, the switchgear is provided with the fixed-side terminal 11 and a movable-side terminal 12 that are connected to an outside power circuit, at both end portions of the housing incorporating the case 101 made of an insulating material; the arc-extinguishing chamber 102 for extinguishing the arc is provided in the side of the fixed-side terminal 11. In the arc-extinguishing chamber 102 in the case 101, the relay unit 104 that is connected to the movable-side terminal 12, detects an abnormal current and issues instructions to open the contacts is accommodated, together with the switch mechanism 103 and others that are the destination to which the instructions to open the contacts is transmitted. The fixed contactor 1 to which the fixed contact 1a is fixed and the movable contactor 2 to which the movable contact 2a is fixed are disposed in the arc-extinguishing chamber 102.

**[0151]** In the fixed contactor 1, a conductor is divided into two-forked conductors, the conductors are extended from the fixed-side terminal 11 toward the case interior up to near the rotation axis 110 of the movable contactor 2, and joined together there, and following that, the joined conductor is folded back toward the fixed-side terminal 11 between the two-forked conductors.

**[0152]** The fixed contact 1a and an arc runner 107 are fixed to the folded-back end portion. The movable contactor 2, although not shown in the figure, is mechanically and electrically connected to the relay unit 104. In order to take in and cool the arc A generated between the fixed contact 1a and the movable contact 2a when the contacts are opened, an arc-extinguishing device in which the plurality of cooling plates 91 are stacked at predetermined intervals is disposed above the fixed contactor 1, facing the tip of the movable contactor 2.

**[0153]** The attraction bar 3 made of a magnetic material is disposed above the arc-extinguishing chamber 102, and the magnet 4 is disposed with its magnetic pole face adjoined (face-joined) to the end face of the attraction bar 3 in the opposite side of the face facing the arc A generated between the contacts 1a and 2a. Therefore, the arc is attracted into the back of the attraction bar 3, and thereby can be easily made to collide with the cooling plates 91, so that interruption reliability can be enhanced.

**[0154]** Moreover, the magnet 4 used for Embodiment in FIG. 33 may be configured using the permanent magnet 41. By configuring the magnet using the permanent magnet 41, a certain amount of magnetic flux can be made to act on the arc A; therefore, stable interruption can be performed even in a region where magnetic flux generated from an energizing conductor is weak (less than 1 kA, for example).

**[0155]** Furthermore, the area of the end face of the attraction bar 3 in the arc-generating space side is made smaller than the average cross-sectional area of the attraction bar 3. Thereby, magnetic field lines distributed inside the attraction bar are concentrated at the tip of the attraction bar 3, the density of magnetic flux generated from the tip of the attraction bar 3 is increased, so that the arc, not shown in the figure, located at the tip of the attraction bar 3 can be quickly attracted toward the attraction bar side.

**[0156]** Furthermore, the normal of the end face of the attraction bar 3 in the arc-generating space side is slanted to the side of the arc A-generating position. In other words, the direction of the magnetic field generated from the tip of the attraction bar 3 is brought close to the arc A-generating direction, thereby increasing the magnetic flux density for attracting the arc A toward the attraction bar side, so that the arc that is not generated on the extension of the axial line of the attraction bar 3 can be easily attracted as well.

**[0157]** In addition, by forming the cooling plates 91 of a metallic material with high thermal conductivity, heat of the arc is quickly transmitted to the cooling plates 91, so that the arc A can be easily deprived of its internal heat energy.

**[0158]** Furthermore, when the cooling plates 91 are made of a metallic material, the arc A is divided by the cooling plates 91 as shown in FIG. 33, the divided arc A is cooled with the heat transmitted to the cooling plates 91, and in addition, a voltage drop occurs at the interface between the arc A and the cooling plates 91 due to an electrode-fall voltage, which will consequently act to reduce a current flowing inside the arc.

#### Embodiment 28.

**[0159]** Next, Embodiment 28, which is a variation of Embodiment 27, will be explained based on FIG. 34. The following embodiments up to Embodiment 34 are variations of Embodiment 27 in which the position of disposing the attraction bar has been changed.

**[0160]** First, Embodiment 28, as shown in FIG. 34, is characterized in that parts (attraction bar 3, magnetic reinforcing plate 6, insulating magnetic-body cover 3c, and permanent magnet 41), the principal part of which is the attraction bar 3, are disposed in the central portion of the arc-extinguishing device, that is, nearly the mid-point between the fixed contact 1a and the movable contact 2a when the contacts are opened at its maximum, as vertically sandwiched between the cooling plates 91. There-

fore, in addition to magnetic drive force from a conductor and the like, an arc-attracting effect by the attraction bar 3 is exerted on the arc A at the mid-portion thereof, and the arc A is thereby extended in the direction of the cooling plates 91 (rightward in FIG. 34), so that the arc A can be easily made to collide with the cooling plates 91.

#### Embodiment 29.

**[0161]** Next, Embodiment 29, which is another variation of Embodiment 27, will be explained based on FIG. 35. As shown in FIG. 35, this Embodiment 29 is characterized in that parts (attraction bar 3, magnetic reinforcing plate 6, insulating magnetic-body cover 3c, and permanent magnet 41), the principal part of which is the attraction bar 3, are disposed under the arc-extinguishing device, near the arc runner 107. In addition, in the configuration of the fixed contactor 1, a portion of the attraction bar 3 in the permanent magnet side is embedded in the case, between the conductors divided from the fixed-side terminal 11.

**[0162]** Thereby, the arc-attracting effect by the attraction bar 3 is exerted on the arc A near the arc runner 107, in addition to magnetic drive force from the conductor and the like. The arc A at the beginning of opening the contacts can be quickly driven to the back of the arc runner 107, so that wear of the contacts can be reduced and contact reliability can be enhanced.

#### Embodiment 30.

**[0163]** Next, Embodiment 30, which is still another variation of Embodiment 27, will be explained based on FIG. 36. This Embodiment 30, as shown in FIG. 36, is characterized in that parts (attraction bar 3, magnetic reinforcing plate 6, insulating magnetic-body cover 3c, and permanent magnet 41), the principal part of which is the attraction bar 3, are disposed above the arc-extinguishing device, with an end face of the attraction bar 3 facing downward and also with the end face located higher than the movable contact 2a in the state of the contact opened at its maximum.

**[0164]** Additionally, the attraction bar 3 is disposed with its portion embedded in the case 101 in this Embodiment 30; however, its disposal is not limited to this in practical applications, but the bar can be disposed inside the case without causing any problem. Thereby, the arc-attracting effect by the attraction bar 3 is exerted on the arc A near the movable contact 2a, and the arc A near the movable contact 2a is extended upward of the arc-extinguishing device, so that interruption capability can be enhanced.

#### Embodiment 31.

**[0165]** Next, Embodiment 31, which is still another variation of Embodiment 27, will be explained based on FIG. 37. This Embodiment 31 is, as shown in FIG. 37, configured in such a way that the permanent magnet 41 is in

a state of its magnetic pole faces facing nearly in the vertical direction, two attraction bars 3, an upper and a lower attraction bar, which are L-shaped with respect to the magnetic pole faces are connected with each other, the permanent magnet 41 is protected by the insulating magnetic-body cover 3c except the portion connected to the attraction bars 3, and furthermore an end portion of the insulating magnetic-body cover 3c is extended toward between the contacts. In addition, this insulating magnetic-body cover 3c is vertically sandwiched by the cooling plates 91.

**[0166]** Thereby, the arc-attracting effect by the attraction bar 3 is exerted on the arc A near the movable contact 2a and the arc runner 107, and the arc A is extended in the right direction of the arc-extinguishing device. Furthermore, since the central portion of the insulating magnetic-body cover 3c protrudes, the arc A touches the cover at this portion, and the cover serves as an obstacle, which also produces an additional effect to bend the arc A, so that interruption capability can be enhanced.

#### Embodiment 32.

**[0167]** Next, Embodiment 32, which is still another variation of Embodiment 27, will be explained based on FIG. 38 and FIG. 39.

**[0168]** This Embodiment 32, as shown in FIG. 38, is configured including parts (attraction bar 3, magnetic reinforcing plate 6, insulating magnetic-body cover 3c, and permanent magnet 41), the principal part of which is two attraction bars 3, and each bar is disposed above the arc runner 107 outside the arc-extinguishing device and near the movable contact 2a when the contacts are opened at its maximum.

**[0169]** Furthermore, FIG. 39 shows the arc-extinguishing chamber when viewed from the side of the fixed-side terminal 11; the attraction bars 3 are disposed perpendicularly to not-shown side walls of the arc-extinguishing chamber (case walls in the front-back direction of this paper face), and also the two attraction bars 3 are disposed on their respective case walls facing each other. Thereby, the arc A is driven toward different case walls between in the movable contact side and in the arc runner side (see FIG. 39); therefore, the arc A is extended and an effect of enhancing interruption capability can be produced.

#### Embodiment 33.

**[0170]** Next, Embodiment 33, which is still another variation of Embodiment 27, will be explained based on FIG. 40 and FIG. 41.

**[0171]** This Embodiment 33, as shown in FIG. 40, is characterized in that a plurality of units are disposed, each including parts (attraction bar 3, magnetic reinforcing plate 6, insulating magnetic-body cover 3c, and permanent magnet 41), the principal part of which is the attraction bar 3, and in addition, these units are separated

from each other by insulating plates 108 that hold the cooling plates 91.

**[0172]** As shown in FIG. 40, the insulating plates 108 each including the attraction bar 3 and one of the cooling plates 91 are disposed between near the arc runner 107 and near the movable contact 2a in the state of the contact opened at its maximum. The arc A is thereby attracted to the attraction bar 3, so as to be driven in the right direction of FIG. 40, and furthermore the arc A is driven and extended in the left direction of FIG. 40 because of the insulating plates 108 protruding. In addition, the arc A is divided by the cooling plates 91, which are the protruding portions, attached to the tip of the insulating plates 108; therefore, the arc voltage is raised, thereby enhancing interruption capability.

**[0173]** Additionally, these attraction bars 3 and others, in Embodiment 33, are arranged to extend the arc A toward the fixed-side terminal 11; however, as the configuration of the essential-part of the arc-extinguishing chamber viewed from the fixed-side terminal 11 as shown in FIG. 41, the attraction bars 3 are perpendicularly attached to a case side wall and the arc A may be extended using ribs 109 formed by projecting portions of the case.

#### Embodiment 34.

**[0174]** Next, Embodiment 34, which is still another variation of Embodiment 27, will be explained based on FIG. 42.

**[0175]** This Embodiment 34 is characterized in that the function of the attraction bar 3 is added to the arc runner 107, which is a traveling conductor; the permanent magnet 41 with a magnetic pole face thereof facing the arc runner 107 is disposed as shown in FIG. 42 at the rear of the arc runner 107 (right direction in FIG. 42). Since the arc runner 107 has a function of holding the arc A, its temperature rises very high when the contacts are opened; therefore, a gap is provided between the arc runner 107 and the permanent magnet 41 in order to protect the permanent magnet 41 from thermally degaussing. The permanent magnet 41 and part of the arc runner 107 are protected from the arc A by the insulating magnetic-body cover 3c, and furthermore the gap between the arc runner 107 and the permanent magnet 41 is also separated by this insulating magnetic-body cover 3c in this Embodiment.

**[0176]** By configuring such as the above, the arc A in the fixed contact side is attracted toward the attraction bar 3, and furthermore the arc runs in the right direction in FIG. 42 on the arc runner 107 that also serves as the traveling conductor, whereby the arc A is extended and the arc voltage is raised, thereby enhancing interruption capability.

#### Embodiment 35.

**[0177]** A switchgear according to Embodiment 35 will be explained based on FIG. 43 next.

**[0178]** In FIG. 43, the fixed contactor 1 to which the fixed contact 1a is fixed and the movable contactor 2 to an end portion of which the movable contact 2a is fixed are disposed; the fixed contactor 1 and the movable contactor 2 are electrically and mechanically connected to an outside circuit. Above the fixed contactor 1 and the movable contactor 2 is disposed an arc-extinguishing device in which the plurality of cooling plates 91 are arranged at predetermined intervals in order to take in and cool the arc A generated between the fixed contact 1a and the movable contact 2a when the contacts are opened. A not-shown exhaust opening is provided in the upper side of the arc-extinguishing device, whereby the switchgear can structurally discharge to the outside thermal gas generated by the arc A.

**[0179]** Furthermore, a fixed-side arc runner 107a and a movable-side arc runner 107b are disposed with the arc-extinguishing device thereby sandwiched from both sides thereof. These are conductors that make the arc A generated between the contacts run to the arc-extinguishing device; the fixed-side arc runner 107a continuously extends from near the fixed contact 1a to near the arc-extinguishing device. Meanwhile, the movable-side arc runner 107b, although not shown in the figure, is electrically and mechanically connected to the movable contactor 2; when the arc A on the movable contactor 2 moves to the movable-side arc runner 107b, the movable contactor 2 is excluded from the conduction path.

**[0180]** The attraction bar 3 that is protected by the insulating magnetic-body cover 3c and made of a magnetic material is disposed in the central portion of the arc-extinguishing device; the magnet 4 is adjoined (face-joined) to the attraction bar and disposed with one of the magnetic pole faces thereof placed on the end face of the attraction bar 3 in the opposite side of the arc A generated between both contacts 1a and 2a, and in addition, the magnetic reinforcing plate 6 is provided in the opposite side of the contacting face between the magnet 4 and the attraction bar 3.

**[0181]** Moreover, an arc holder 106 that is not protected by the insulating magnetic-body cover 3c is provided on part of the attraction bar 3. Thereby, when the arc A attracted by the attraction bar 3 reaches the unprotected portion by the insulating magnetic-body cover 3c, the arc A forms a spot at this portion, which is stably maintained.

**[0182]** Next, the arc-extinguishing process in interrupting current in Embodiment 35 will be explained hereinafter.

**[0183]** When the switchgear is opened, the arc A is generated between the fixed contact 1a and the movable contact 2a that had been closed and in a conduction state. The arc A is driven toward the arc-extinguishing device by the effects of magnetic drive force accompanied by a current flowing through the fixed contact 1a and the movable contact 2a, an increase in pressure inside the arc-extinguishing chamber attributed to the arc occurrence, gas flow associated with discharging of thermal gas to outside the case, magnetic attraction force by



the cooling plates 91, and so forth.

**[0184]** Therefore, the arc A on the fixed contact 1 a moves to the fixed-side arc runner 107a that has a continuous conductor structure; meanwhile, the arc A in the movable contact side changes its flow to the arc runner near the movable contact when the contacts are opened and the movable contact 2a comes close to the movable-side arc runner 107b.

**[0185]** When the arc A in the fixed side and movable sides moves to the arc runners, the arc A on the arc runners undergoes, as shown in Embodiment 1, driving force that drives the arc in the direction toward the cooling plates 91 (upward in FIG. 43), by the arc-attracting effect by the attraction bar 3; thereby, the mid-portion of the arc A is attracted to the central portion of the arc-extinguishing device and maintained at the arc holder 106, and furthermore the arc A on the arc runners in the fixed and movable sides also moves upward, whereby the arc as a whole is divided by the cooling plates 91. The arc A can be stably made to collide with the cooling plates 91 by the attraction bar 3, thereby producing an effect of enhancing interruption capability.

**[0186]** Additionally, either the permanent magnet 41 or the electromagnet 5 can be chosen for the magnet 4 depending on a current to be interrupted; the arc A can be quickly attracted by the permanent magnet 41 in a relatively small current region, whereas in a relatively large current region, the arc A can be stably attracted by using the electromagnet 5 without thermally degaussing the magnet.

#### Embodiment 36.

**[0187]** Next, a switchgear according to Embodiment 36 will be explained based on FIG. 44.

**[0188]** In FIG. 44, the switchgear is provided with terminals connected to an outside power circuit, at both end portions of a housing incorporating a case made of an insulating material; a terminal at one of the end portions is connected to a first fixed contactor 1 that has a first fixed contact 1a, and another terminal at the other end portion is provided with a second fixed contactor 1 that has a second fixed contact 1a; and an arc-extinguishing chamber for extinguishing arcs A is provided near end portions of two fixed contacts 1 a and two fixed contactors 1.

**[0189]** In the arc-extinguishing chamber are accommodated a not-shown relay unit that detects an abnormal current and issues instructions to open the contacts, a not-shown switch mechanism equipped with a rotation mechanism, which is a destination to which the instructions to open the contacts are transmitted, and so forth. In the arc-extinguishing chamber, the movable contactor 2 that has two movable contacts 2a is disposed facing the fixed contactors 1.

**[0190]** When the switchgear is in the closed state, the two movable contacts 2a contact their respective two fixed contacts 1 a, and both fixed contactors 1 and 2

become connected via the movable contactor 2. In order to take in and cool the arcs A generated between the fixed contacts 1a and the movable contacts 2a when the contacts are opened, arc-extinguishing devices each provided with the plurality of cooling plates 91 stacked at predetermined intervals are disposed above the fixed contactors 1, facing their respective tips of the movable contactor 2.

**[0191]** Furthermore, this Embodiment is characterized in that above the arc-extinguishing devices, the attraction bar 3 made of a magnetic material is disposed in a position facing the movable contactor 2 in the state of the contacts opened at their maximum, extending so as to come close to the space sandwiched between the tip portions of the movable contactor 2 in the open state, and the magnet 4 is disposed with a magnetic pole face adjoined (face-joined) to the end face of the attraction bar 3 in the opposite side of the face facing the arcs A generated between both contacts (the attraction bar 3 face-joined to the magnetic pole face of the magnet 4).

**[0192]** Next, the arc-extinguishing process of interrupting current in Embodiment 36 will be explained herein-after.

**[0193]** When the switchgear is opened in FIG. 44(a), the arcs A are generated between their respective fixed contacts 1a and movable contacts 2a that had been closed and in a conduction state. Both arcs A are driven toward the arc-extinguishing devices by the effects of magnetic drive force accompanied by a current flowing through the fixed contacts 1a and the movable contacts 2a, an increase in pressure inside the arc-extinguishing chamber attributed to the arc occurrence, gas flow associated with discharging of thermal gas to outside the case, magnetic attraction force by the cooling plates 91, and so forth.

**[0194]** Since the directions of the currents flowing inside both arcs are opposite to each other, repulsion force acts on each arc. When one of the arcs is attracted toward the cooling plates 91, the other is driven in the direction of getting away from the plates. Therefore, it becomes difficult to divide both arcs A at the same time by the cooling plates 91; however, if the arc-attracting effect is added by the attraction bar 3 as has been described in Embodiment 1, both arcs A are extended in the direction toward the cooling plates 91 (rightward in FIG. 44), and stably divided by the cooling plates 91, so that interruption reliability can be enhanced.

**[0195]** Next, when the arc-extinguishing process of the arcs A progresses in FIG. 44(b), the arcs A attracted into the back of the attraction bar 3 join together and become connected without via the movable contactor 2. When coming into this state, the arcs A can be more easily divided by the cooling plates 91, and in addition, wear of the movable contacts 2a and movable contactor 2 can be suppressed, so that contact reliability between the fixed and movable contacts in the closed state can be enhanced.

**[0196]** Additionally, by protecting the periphery of the

attraction bar 3 with the insulating magnetic-body cover 3c, effects of cooling the arcs A are added near the attraction bar, so that interruption reliability can be further enhanced.

**[0197]** Moreover, the attraction bar 3 is entirely protected by the insulating magnetic-body cover 3c in FIG. 44; however, if the bar is connected to the movable contactor 2 with a conductor so as to make its potential the same, and part of the attraction bar 3 is exposed to the arcs A so that the arcs A can change their flow to the attraction bar 3, wear of the contacts can be further suppressed as well.

**[0198]** Additionally, the attraction bar 3 in FIG. 44 is disposed in a position facing the tips of the movable contactor when the contacts are opened, the disposing position is not limited to this, but the attraction bar 3 and the magnet 4 may be disposed near the fixed contactors, for example. When the attraction bar 3 and the magnet 4 are disposed near the fixed contactors, the arcs A can be quickly attracted when the contacts are opened, so it becomes possible to divide the arcs A by the cooling plates from the beginning of opening the contacts.

**[0199]** Additionally, combinations of each embodiment, or suitable alterations and omissions of each embodiment will be apparent within the scope of this invention.

#### INDUSTRIAL APPLICABILITY

**[0200]** The present invention is preferably applied to switchgears, such as switches, circuit breakers, electromagnetic contactors and relays, which interrupt electric current.

#### DESCRIPTION OF THE REFERENCE NUMERALS

##### **[0201]**

A	arc	
M	magnetic field lines	
1	fixed contactor	
1a	fixed contact	
2	movable contactor	
2a	movable contact	
11	fixed-side terminal	
12	movable-side terminal	
15	flexible conductor	
3	attraction bar	
31	attraction bar	
32	attraction bar	
3c	insulating magnetic-body cover	
3cc	thickness of insulating magnetic-body cover	
3d	uneven portion of insulating magnetic-body cover	
3e	recess	
4	magnet	
41	permanent magnet	
4c	magnet cover	

4d	uneven portion of magnet cover
42	bar magnet
5	electromagnet
5A	first electromagnet (electromagnet in attraction bar side)
5B	second electromagnet (electromagnet in opposite side of attraction bar)
6	magnetic reinforcing plate
6c	magnetic reinforcing plate cover
10	7 magnetic yoke
7c	magnetic yoke cover
67	combined magnetic reinforcing plate and magnetic yoke
8	magnetic guide plate
15	8c magnetic guide plate cover
9	cooling bars
91	cooling plates
100	switchgear
101	case
20	102 arc-extinguishing chamber
103	switch mechanism
104	relay unit
105	electromagnetic actuator unit
106	arc holder
25	107 arc runner
107a	fixed-side arc runner
107b	movable-side arc runner
108	insulating plates
109	ribs
30	110 rotation axis
111	traveling electric path

#### **Claims**

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##### **1. A switchgear, comprising:**

a fixed contactor that has a fixed contact;  
 a movable contactor that has a movable contact;  
 a switch mechanism that opens and closes the fixed contact and the movable contact;  
 a magnet that generates a magnetic field for extending an arc generated between the fixed contactor and the movable contactor when the fixed contact and the movable contact are opened; and  
 an elongated magnetic body one end portion of which contacts one of the magnetic pole faces of the magnet; wherein  
 the other end portion of the magnetic body is disposed close to the arc-generating area between the fixed contactor and the movable contactor, and the arc is extended by the magnetic field generated by the magnet, along a longitudinal side face of the magnetic body.

##### **2. A switchgear according to claim 1, wherein the switchgear is provided with an arc-ex-**

tending space portion and the magnet is disposed in the arc-extending space portion.

3. A switchgear according to claim 1 or 2,  
wherein an insulating resin material is interposed between the magnet and the magnetic body. 5
4. A switchgear according to claim 1 or 2,  
wherein a coil-shaped conductor is wound around the other end portion of the magnetic body, and at least part of the magnetic body is configured as a first electromagnet for the magnet. 10
5. A switchgear according to claim 4,  
wherein the magnet is made of a permanent magnet. 15
6. A switchgear according to claim 5,  
wherein a second electromagnet that can generate magnetic field lines in a direction of cancelling out magnetic field lines generated from the first electromagnet is disposed on the other magnet pole face of the permanent magnet. 20
7. A switchgear according to any one of claims 1 and 6,  
wherein the other end portion of the magnetic body is thinned in such a way that the cross-sectional area of the magnetic body gradually decreases toward the other end portion. 25
8. A switchgear according to any one of claims 1 and 7,  
wherein the one end portion of the magnetic body is thickened in such a way that the cross-sectional area of the magnetic body gradually increases toward the one end portion. 30
9. A switchgear according to claim 7 or 8,  
wherein the thinned portion of the magnetic body is slanted. 35
10. A switchgear according to any one of claims 1 and 9,  
wherein at least part of an outer peripheral surface of the magnetic body is covered with an insulating magnetic-body cover. 40
11. A switchgear according to claim 10,  
wherein the insulating magnetic-body cover is increased in thickness near the contacting face between the magnetic body and the magnet. 45
12. A switchgear according to claim 10 or 11,  
wherein a recess or a projection is formed in at least part of an outer peripheral surface of the insulating magnetic-body cover. 50
13. A switchgear according to any one of claims 1 to 12,  
wherein a cooling plate or a cooling bar is disposed in part of the arc-extending space portion spreading over an outer side face of the magnetic body or that

of the insulating magnetic-body cover so that the arc is made to collide therewith.

14. A switchgear according to claim 13,  
wherein the cooling plate or the cooling bar is formed of a metallic material.
15. A switchgear according to claim 13,  
wherein the cooling plate or the cooling bar is formed of an ablative resin material.
16. A switchgear according to any one of claims 10 and 15,  
wherein a magnetic yoke formed of a magnetic material is disposed in at least part of the arc-extending space portion spreading over the outer side face of the magnetic body or that of the insulating magnetic-body cover, and the arc-extending space portion is sandwiched between the magnetic yoke and the magnetic body or between the magnetic yoke and the insulating magnetic-body cover.
17. A switchgear according to claim 16,  
wherein at least part of the magnetic yoke's surface exposed to the arc is covered with an insulating magnetic yoke cover.
18. A switchgear according to any one of claims 1 and 17,  
wherein at least part of the magnet is covered with an insulating magnet cover.
19. A switchgear according to any one of claims 1 and 18,  
wherein a magnetic reinforcing plate made of a magnetic material is provided on the other magnetic pole face of the magnet.
20. A switchgear according to claim 19,  
wherein the magnetic reinforcing plate is expanded in a direction coming close to the arc-generating area.
21. A switchgear according to any one of claims 16, 17, 19, and 20,  
wherein the magnetic reinforcing plate is integrally formed with the magnetic yoke.
22. A switchgear according to any one of claims 19 to 21,  
wherein part of an exposed surface of the magnetic reinforcing plate, facing the arc-generating area side is covered with an insulating magnetic reinforcing plate cover.
23. A switchgear according to any one of claims 1 and 22,  
wherein a magnetic guide plate made of a magnetic material is disposed facing the one end portion of

the magnetic body, in the arc-generating area between the fixed contactor and the movable contactor, the arc-generating area is sandwiched between this magnetic guide plate and the magnetic body, and in addition, at least part of an exposed surface of the magnetic guide plate, facing the arc-generating area side is covered with a magnetic guide plate cover.

24. A switchgear according to claim 23, wherein the magnetic guide plate is disposed in both sides of the arc-generating area between the fixed contactor and the movable contactor so that the arc-generating area is sandwiched by the magnetic guide plate.

25. A switchgear according to any one of claims 10 to 13, 16 to 18, and 22 to 23, wherein any two of the insulating magnetic-body cover, the magnet cover, the magnetic yoke cover, the magnetic reinforcing plate cover, and the magnetic guide plate cover are paired, and the pair is integrally molded.

26. A switchgear according to any one of claims 10 to 13, 16 to 18, and 22 to 23, wherein at least any one of the insulating magnetic-body cover, the magnet cover, the magnetic yoke cover, the magnetic reinforcing plate cover, and the magnetic guide plate cover is formed of an ablative resin material.

27. A switchgear according to any one of claims 10 to 13, 16 to 18, and 22 to 23, wherein at least any one of the insulating magnetic-body cover, the magnetic yoke cover, the magnetic reinforcing plate cover, and the magnetic guide plate cover is made of a material with a melting point lower than that of the magnet cover.

28. A switchgear according to any one of claims 1 and 27, wherein a plurality of pairs of the fixed contactor and the movable contactor are provided, the magnetic body is divided into a plurality of magnetic bodies or a plurality of magnetic bodies are provided, each of one end portions of the magnetic bodies is brought close to a plurality of arc-generating areas between their respective pairs of the fixed contactor and the movable contactor, and each of the other end portions of the magnetic bodies is contacted to any one of the magnetic pole faces of the magnet.

29. A switchgear according to any one of claims 1 and 28, wherein at least two pairs of the contactors that are electrically connected to an outside conductor and can be opened and/or closed and a plurality of elongated magnet bodies for extending at least two arcs

generated between at least the two pairs of the contactors are provided, and any one of the magnet bodies is made shorter than at least the other magnet body.

30. A switchgear according to any one of claims 1 and 29, wherein opening timing of a movable contactor of at least a pair out of the pairs of the fixed contactor and the movable contactor is delayed from that of a movable contactor of at least the other pair.

31. A switchgear, comprising:

a fixed contactor that has a fixed contact;  
a movable contactor that has a movable contact;  
a switch mechanism that opens and closes the fixed contact and the movable contact;  
an arc-extending space for extending an arc generated between the fixed contactor and the movable contactor; and  
a bar magnet that generates a magnetic field for extending the arc; wherein  
a longitudinal side face of the bar magnet is protected by an insulating magnet cover, one end portion of a magnetic pole face of the bar magnet is disposed in the arc-extending space so as to come close to an arc-generating position between the fixed contactor and the movable contactor, and the arc is extended by the magnetic field generated by the bar magnet, along the longitudinal side face of the bar magnet and winds around the magnet.

32. A switchgear according to claim 31, wherein a recess or a projection for attracting and compressing the arc is provided in at least part of the magnet cover.

33. A switchgear, comprising:

a fixed contactor that has a fixed contact;  
a movable contactor that has a movable contact;  
a switch mechanism that opens and closes the fixed contact and the movable contact;  
an arc-extending space for extending an arc generated between the fixed contactor and the movable contactor; and  
a magnet that generates a magnetic field for extending the arc; wherein  
the magnet is disposed at an edge of the extended arc in the arc-extending space, an uneven insulating magnet cover is provided on a side face other than magnetic pole faces of the magnet, and the arc is attracted into a recess of the magnet cover and compressed by the magnetic field generated by the magnet.

FIG. 1

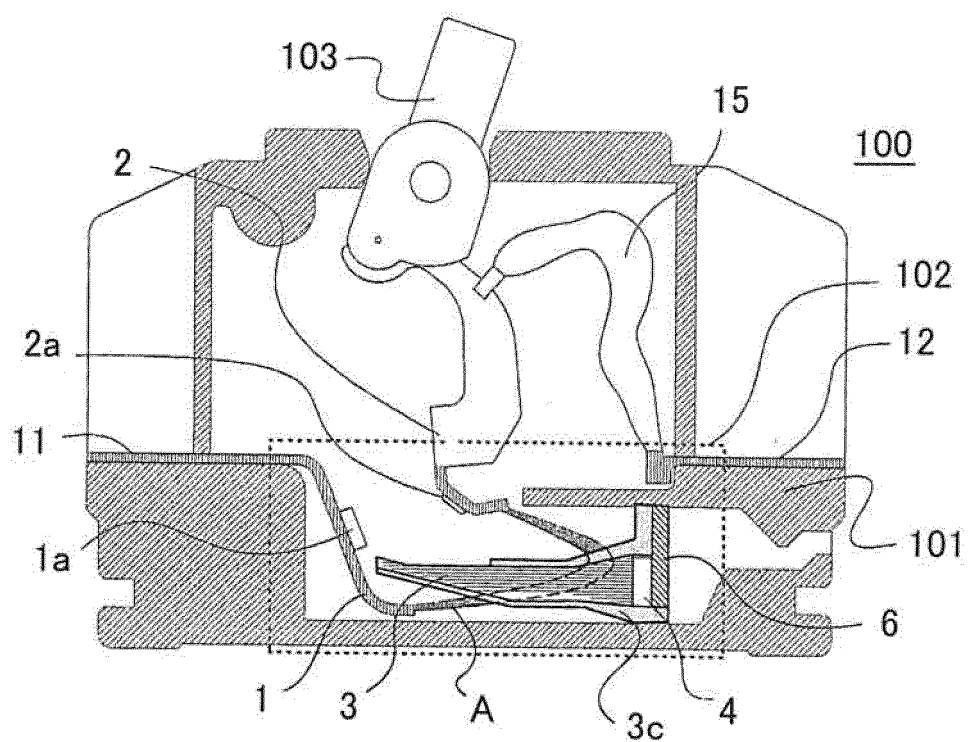


FIG. 2

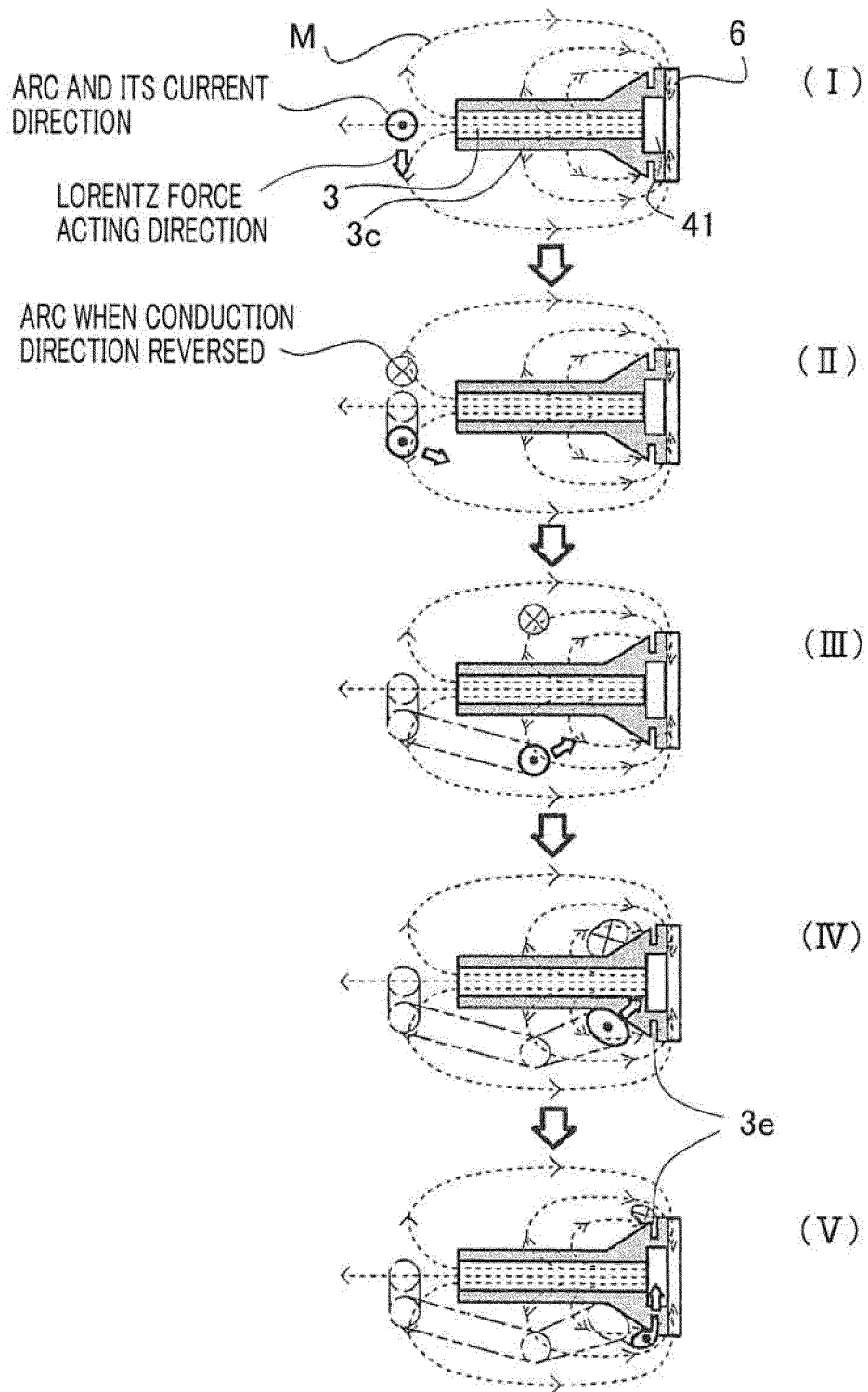


FIG. 3

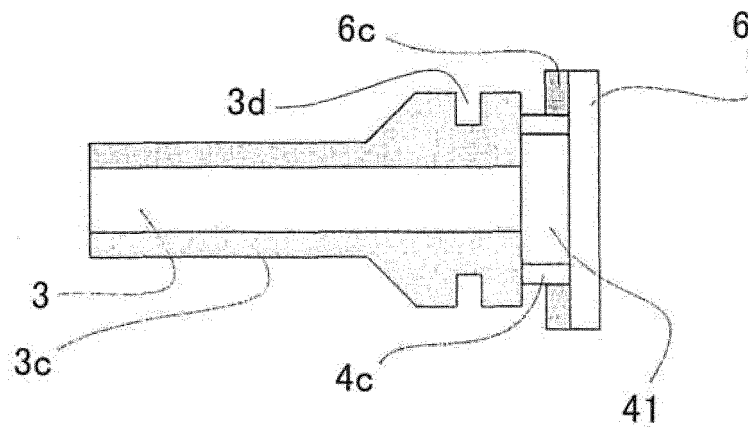


FIG. 4

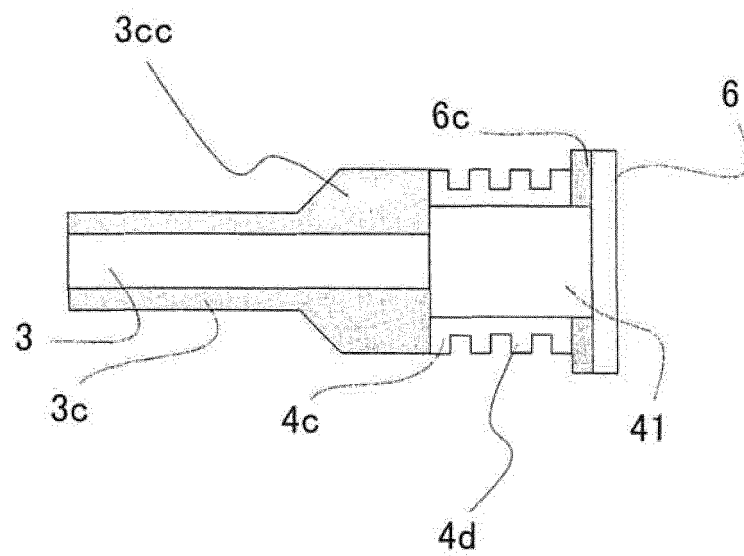


FIG. 5

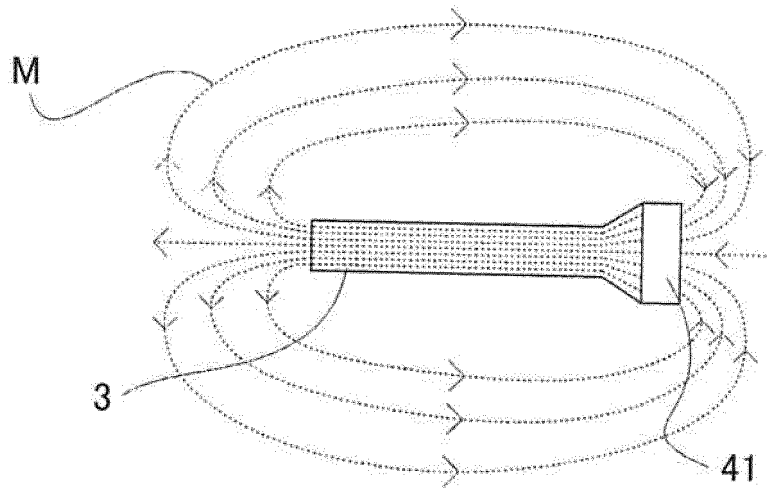


FIG. 6

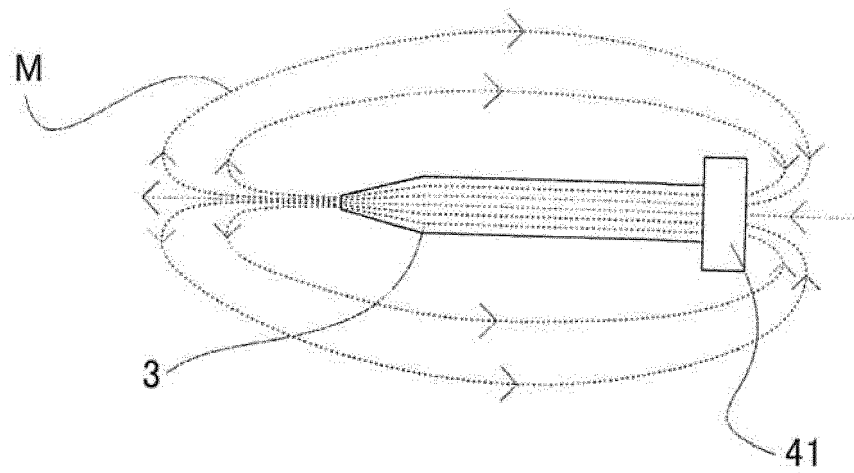




FIG. 7

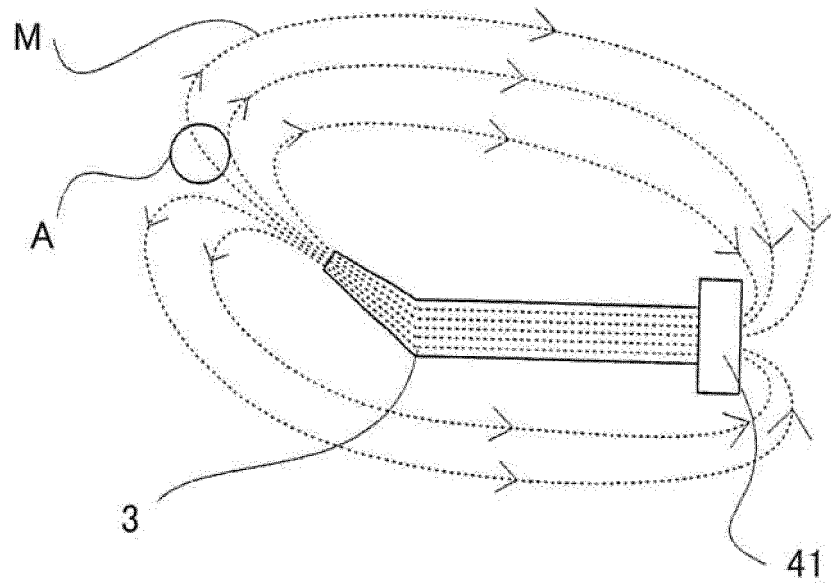


FIG. 8

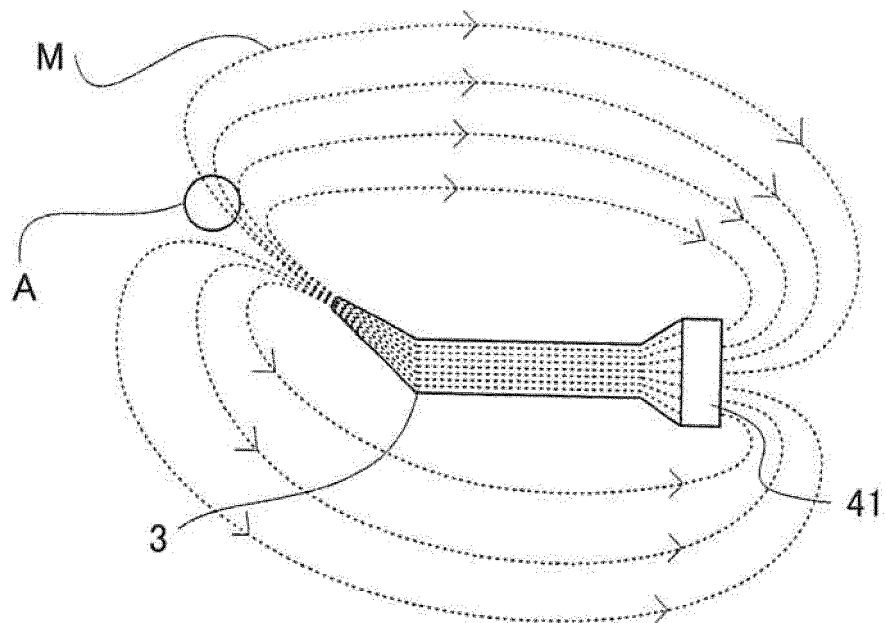


FIG. 9

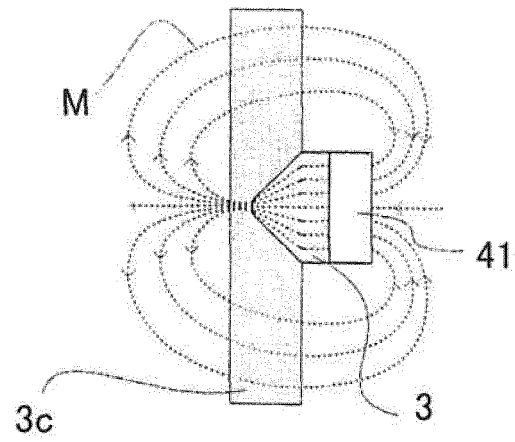


FIG. 10

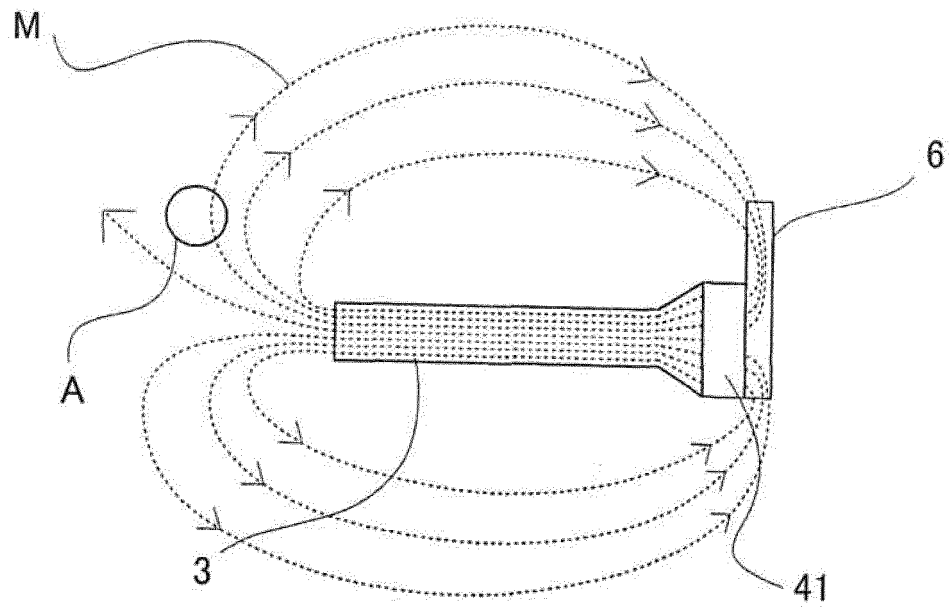


FIG. 11

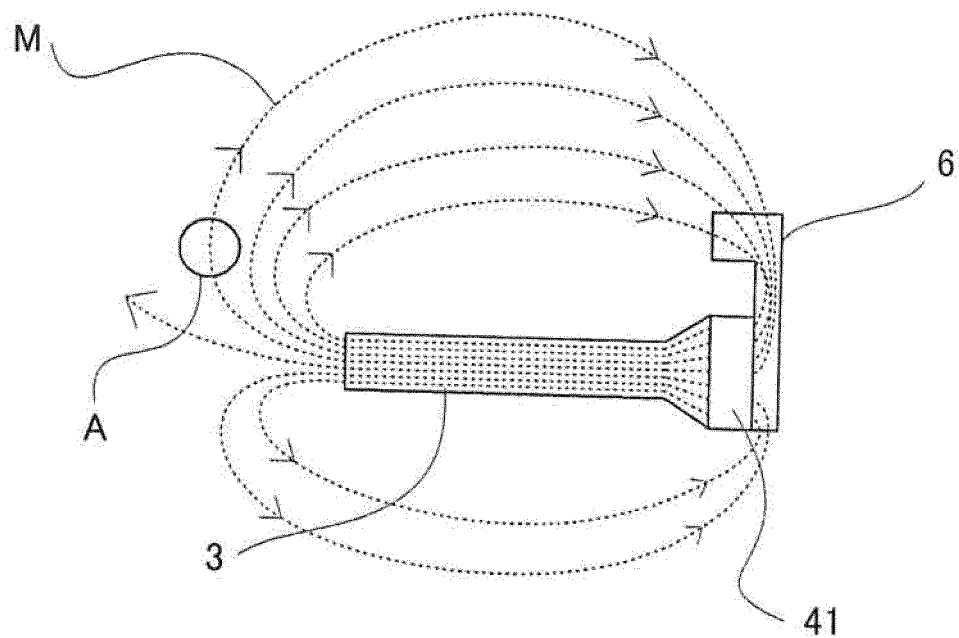


FIG. 12

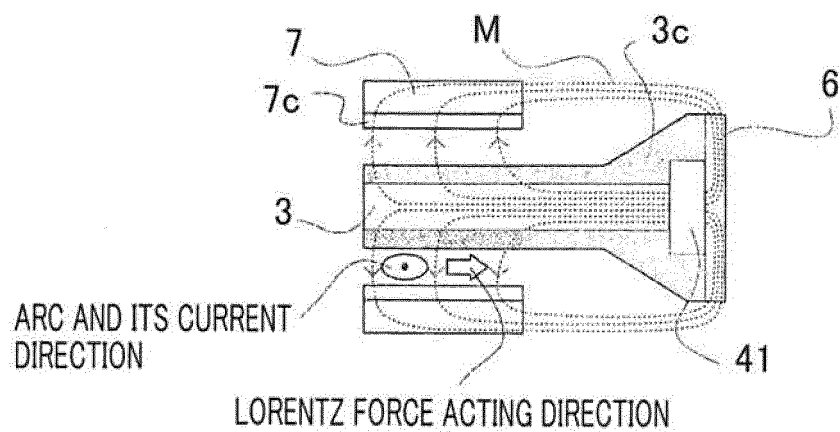


FIG. 13

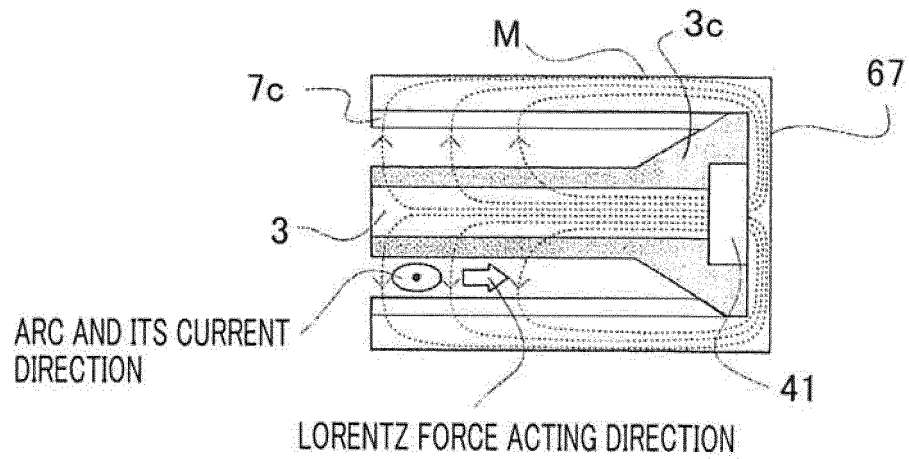


FIG. 14

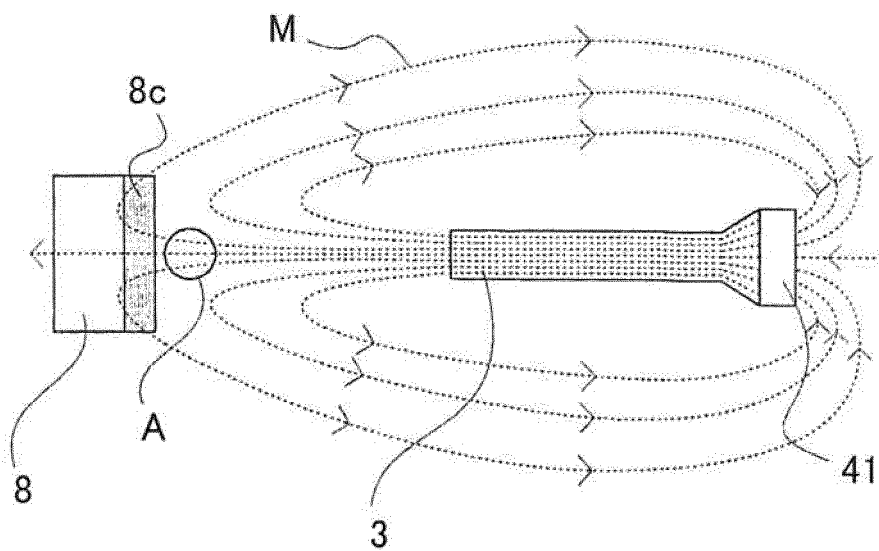


FIG. 15

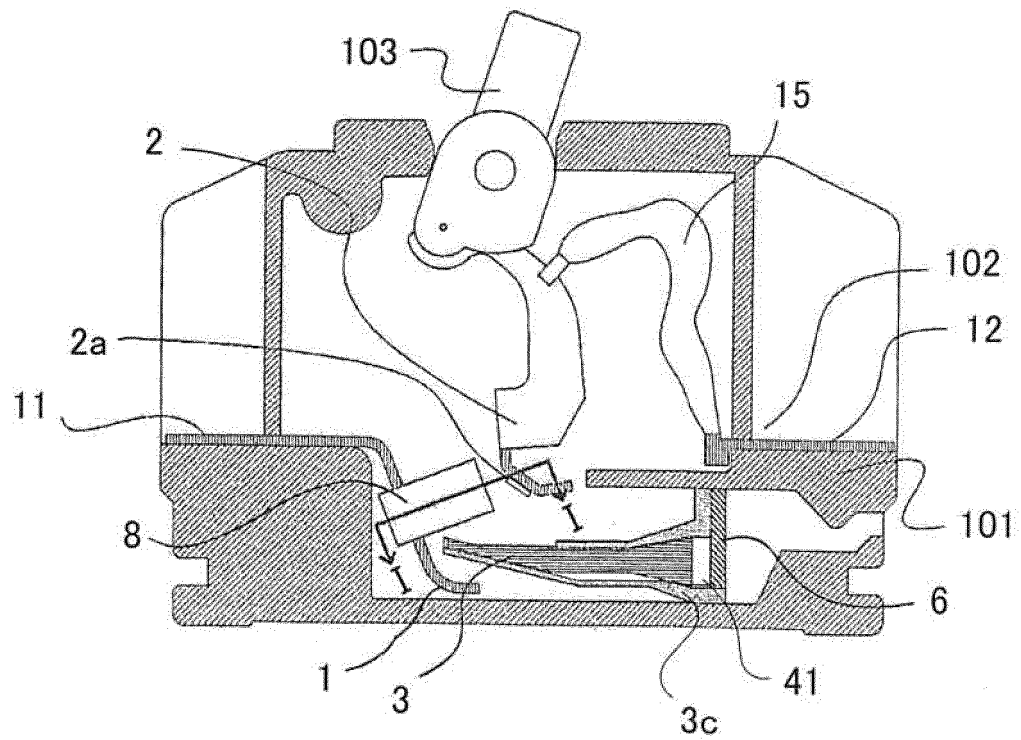


FIG. 16

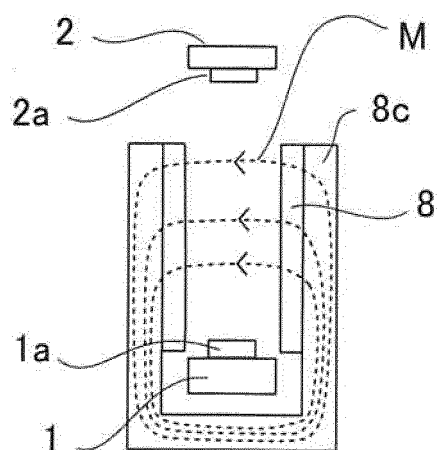


FIG. 17

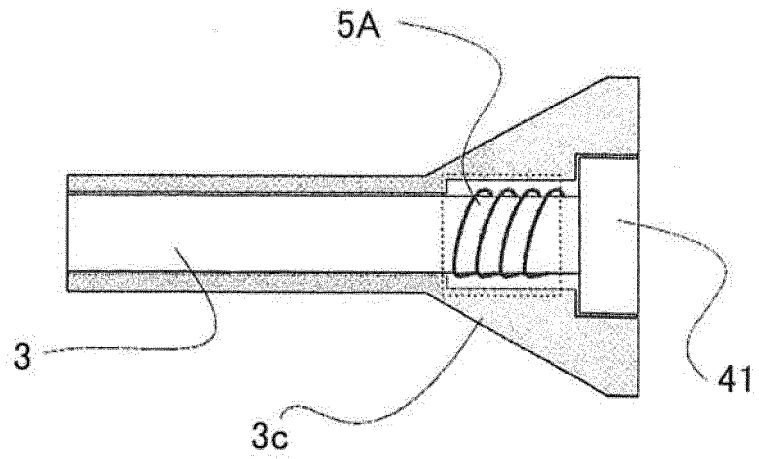


FIG. 18

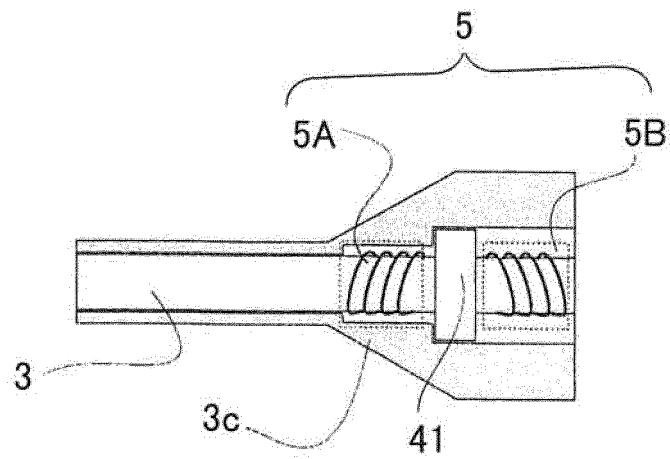


FIG. 19

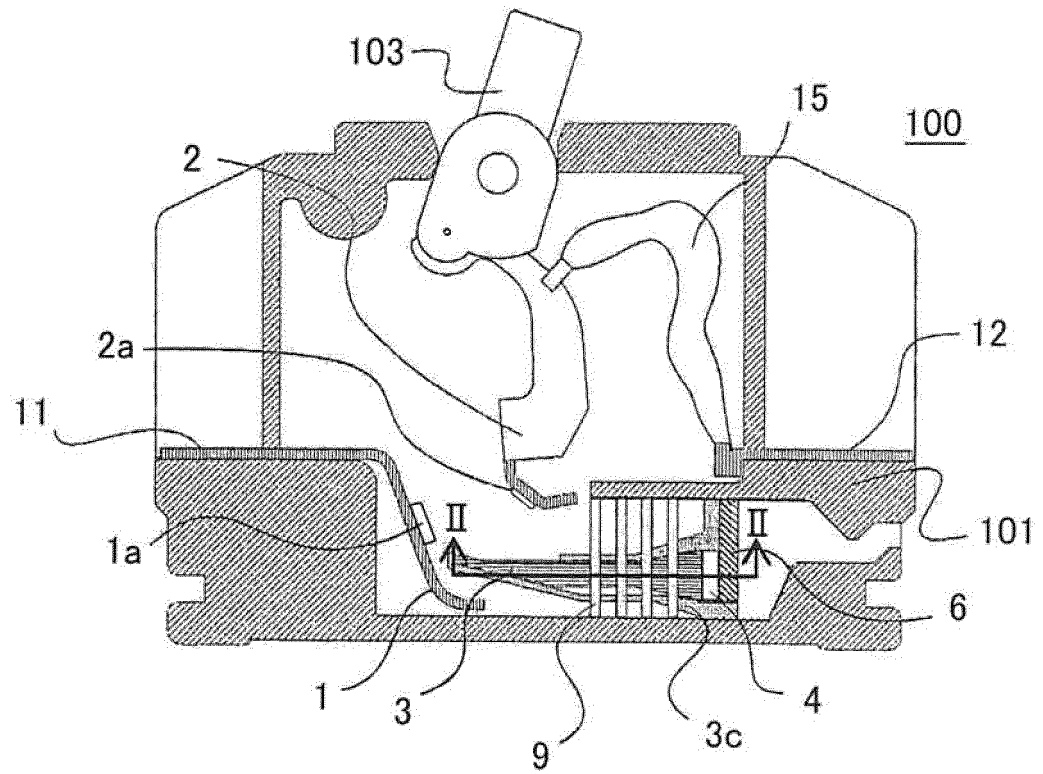


FIG. 20

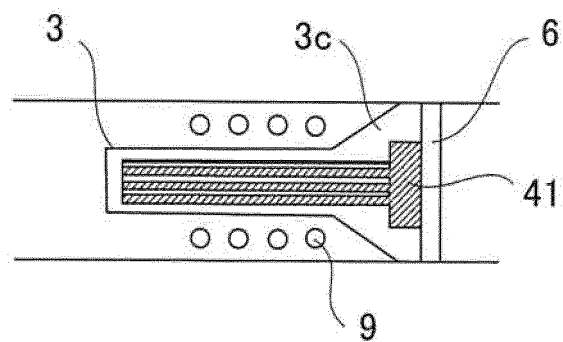


FIG. 21

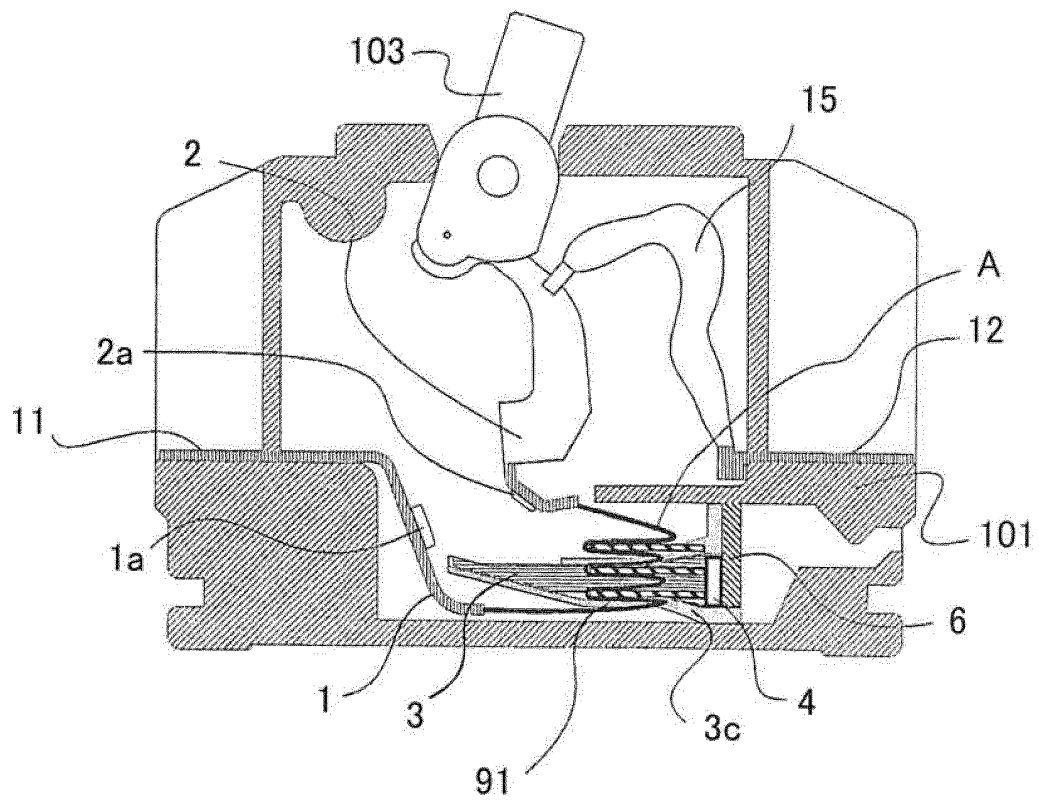


FIG. 22

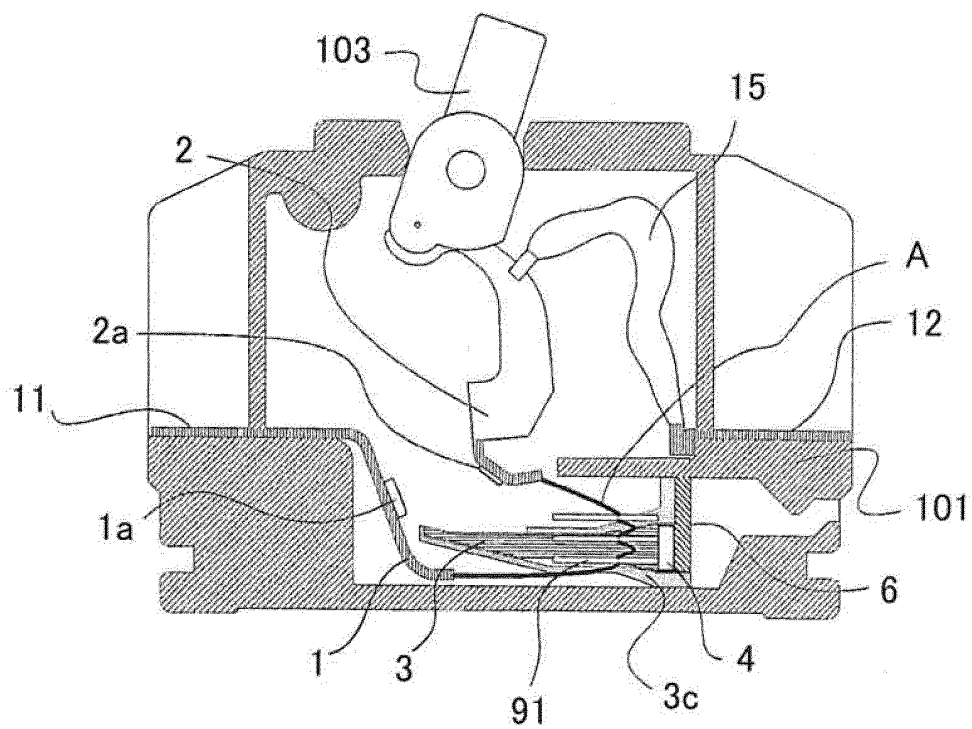




FIG. 23

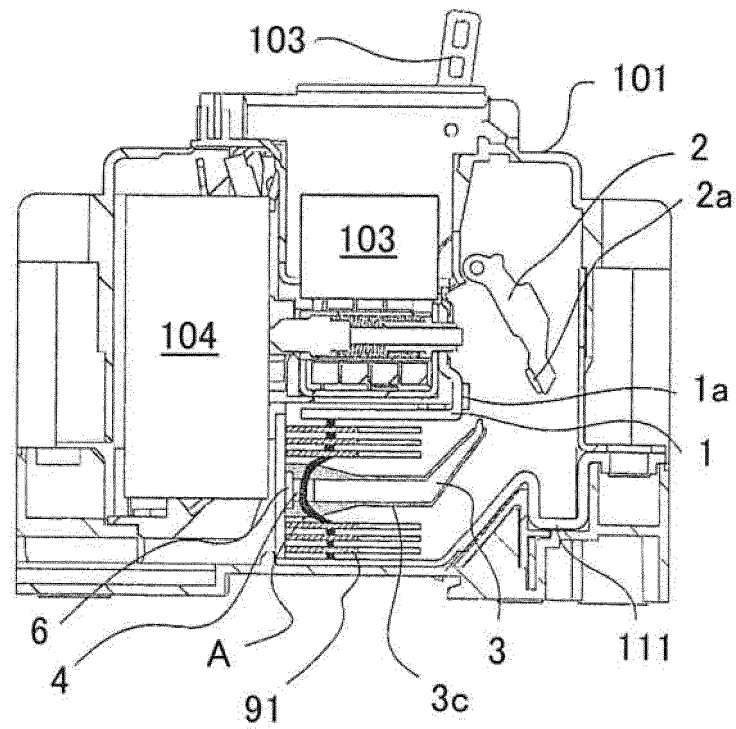


FIG. 24

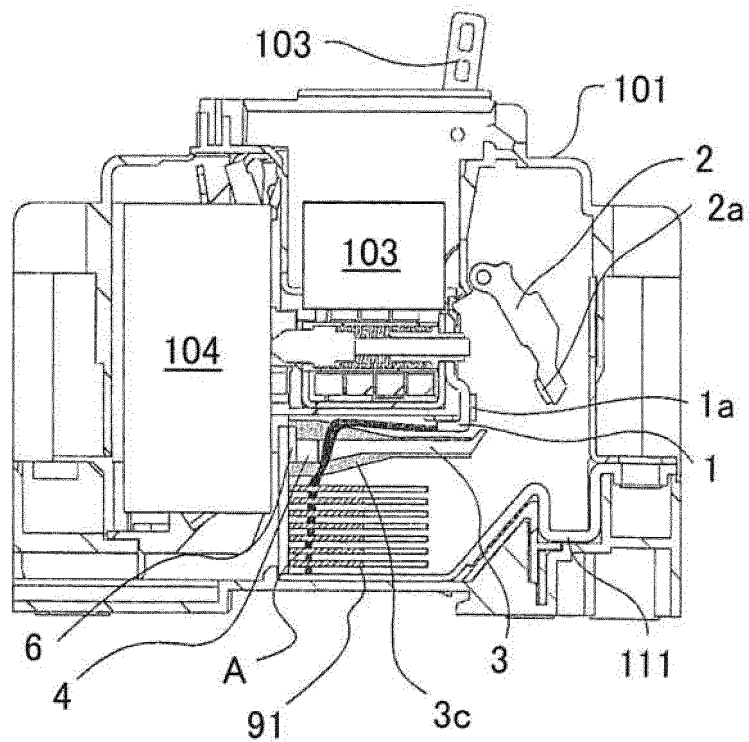


FIG. 25

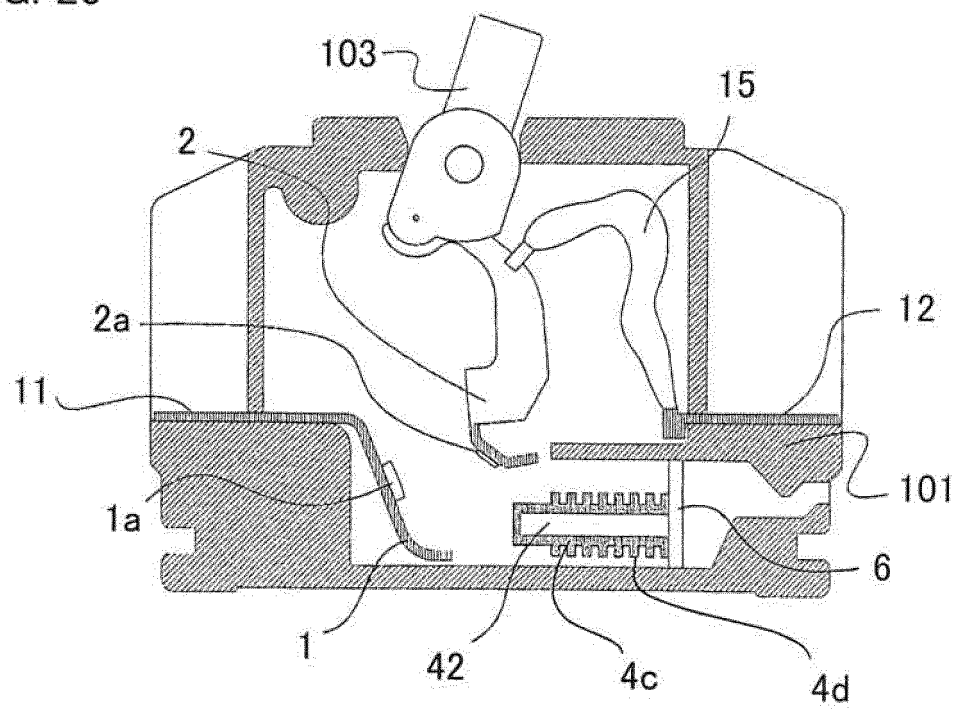


FIG. 26

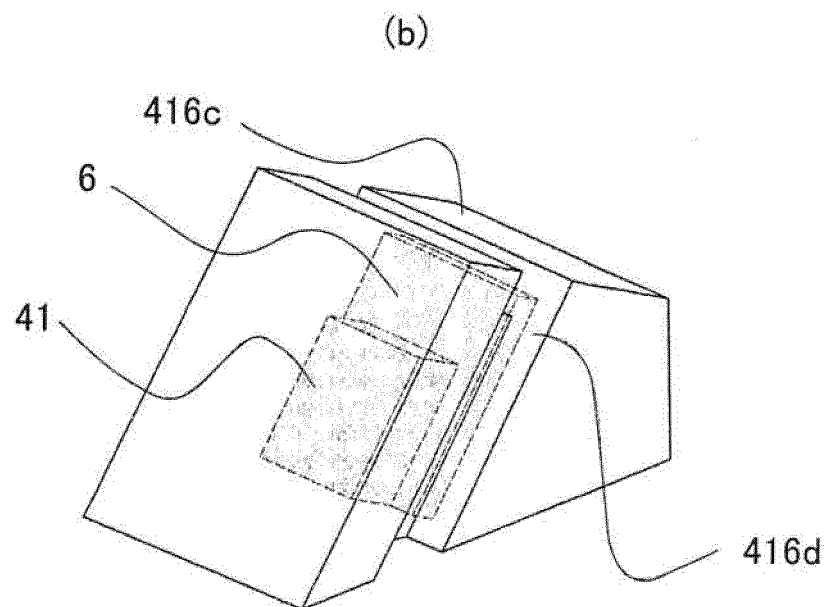
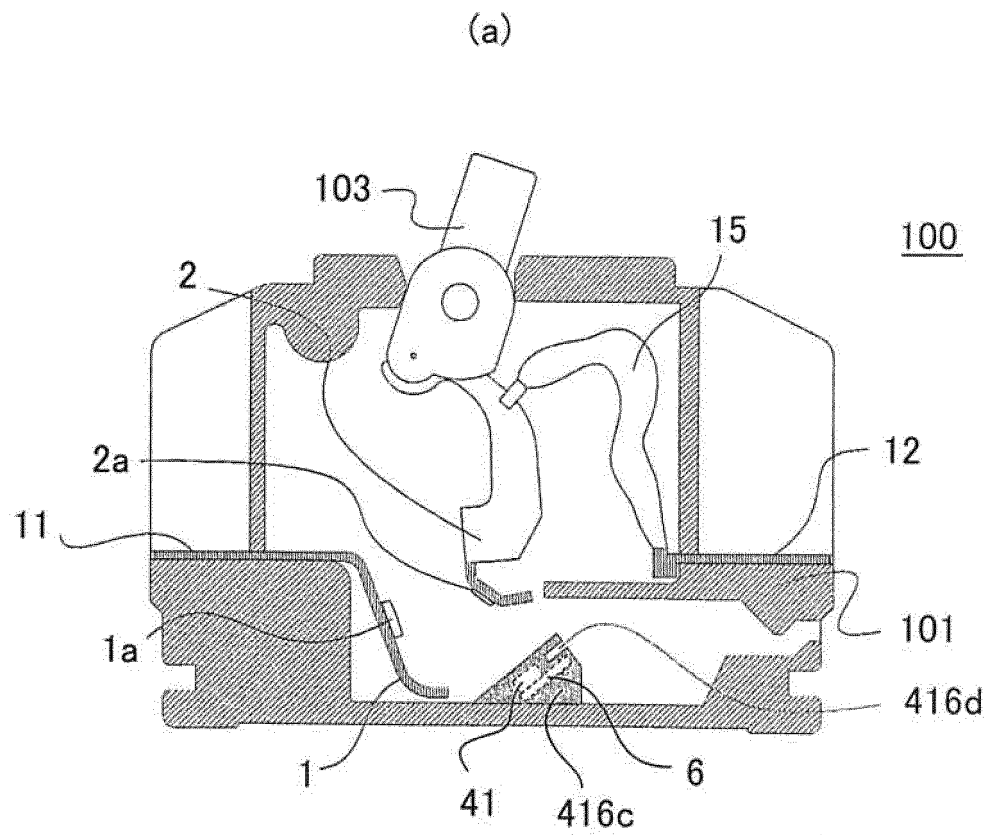


FIG. 27

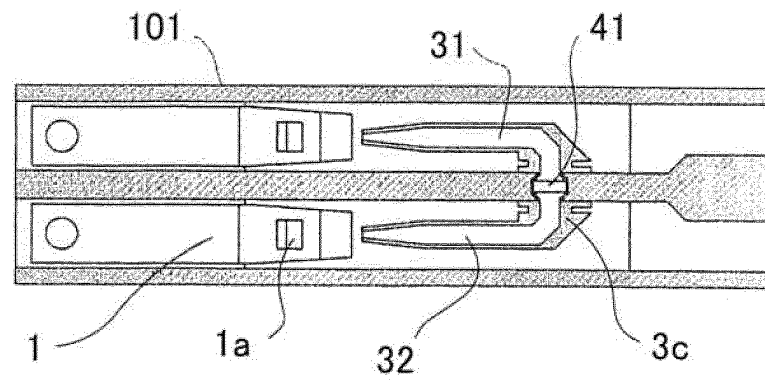


FIG. 28A

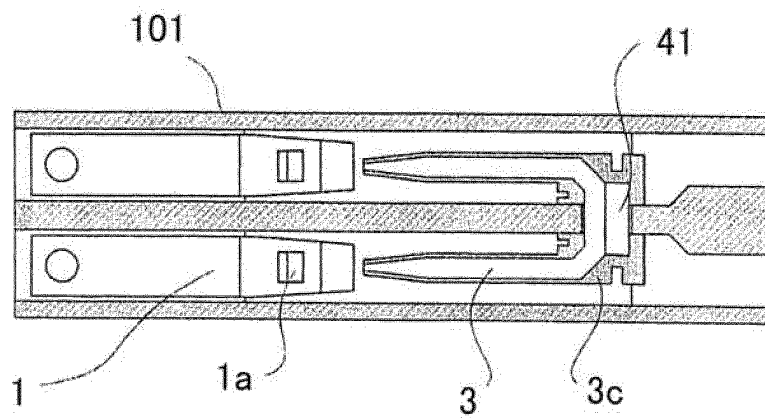


FIG. 28B

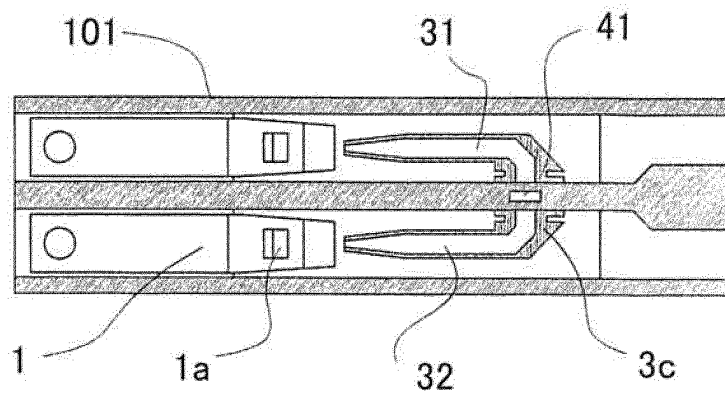


FIG. 28C

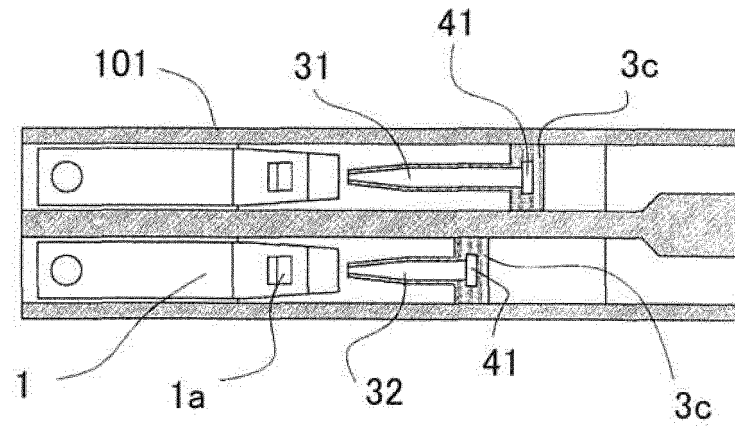


FIG. 29

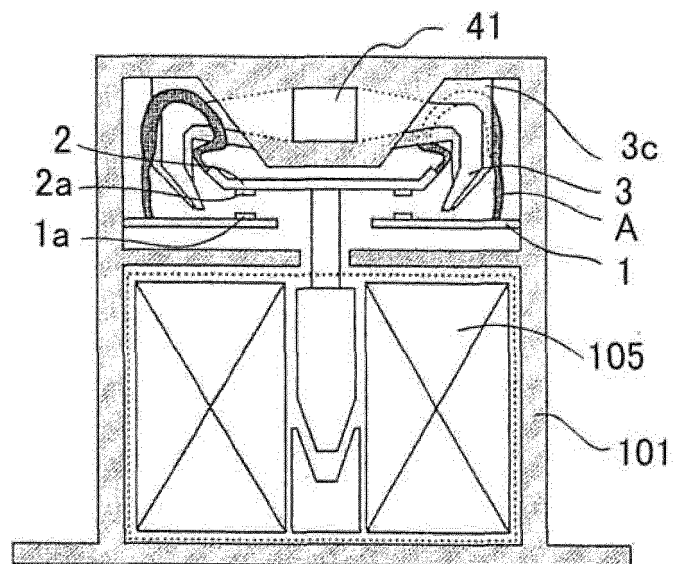


FIG. 30

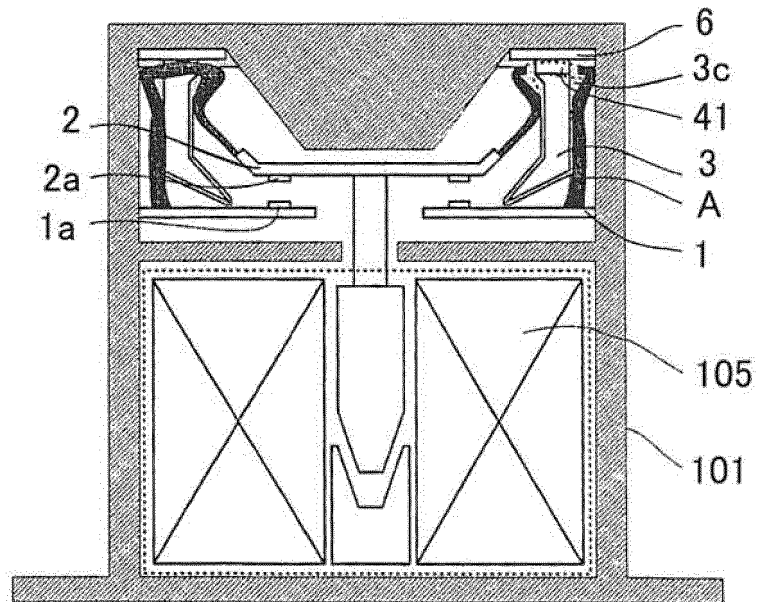


FIG. 31

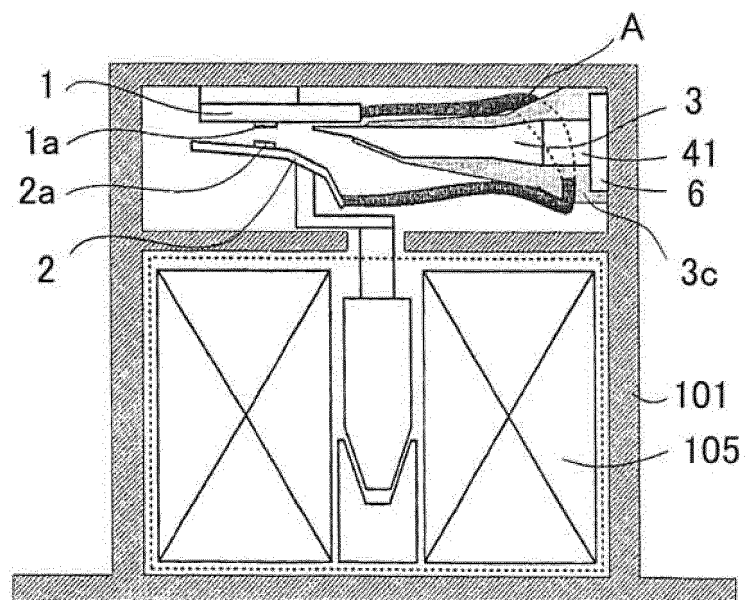


FIG. 32

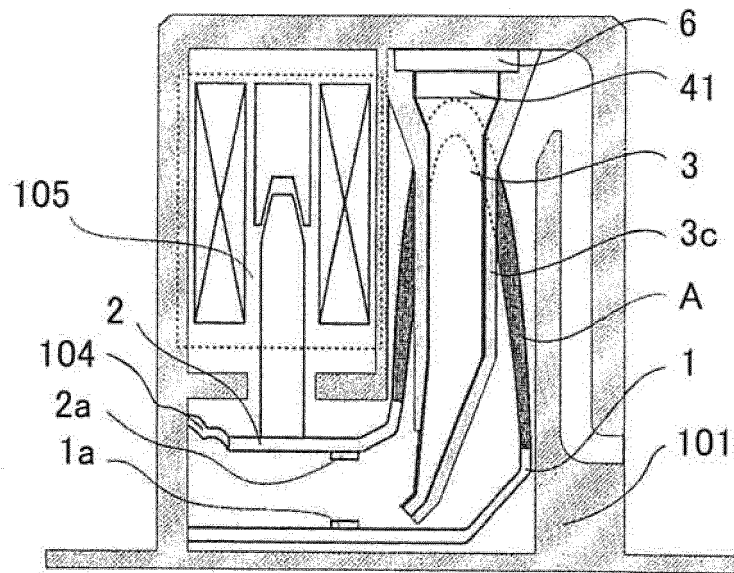


FIG. 33

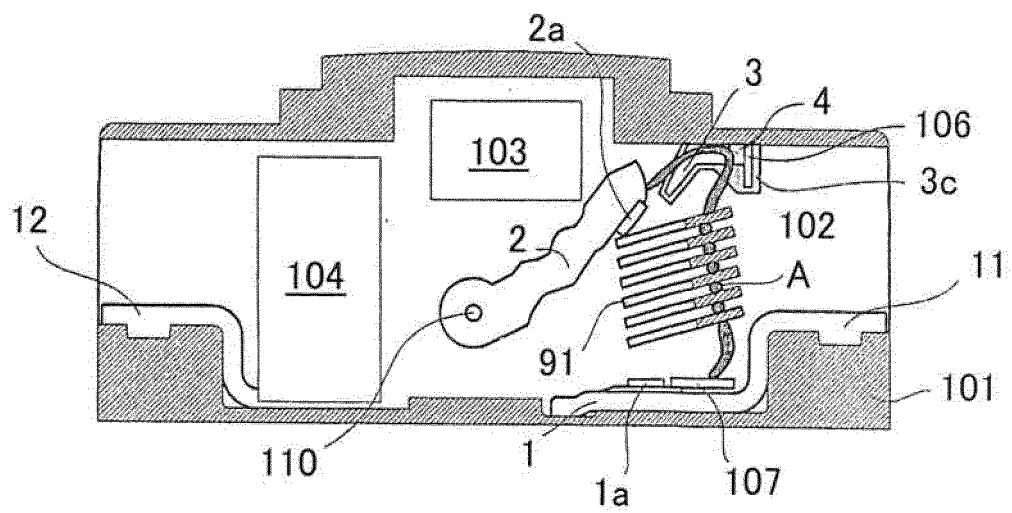


FIG. 34

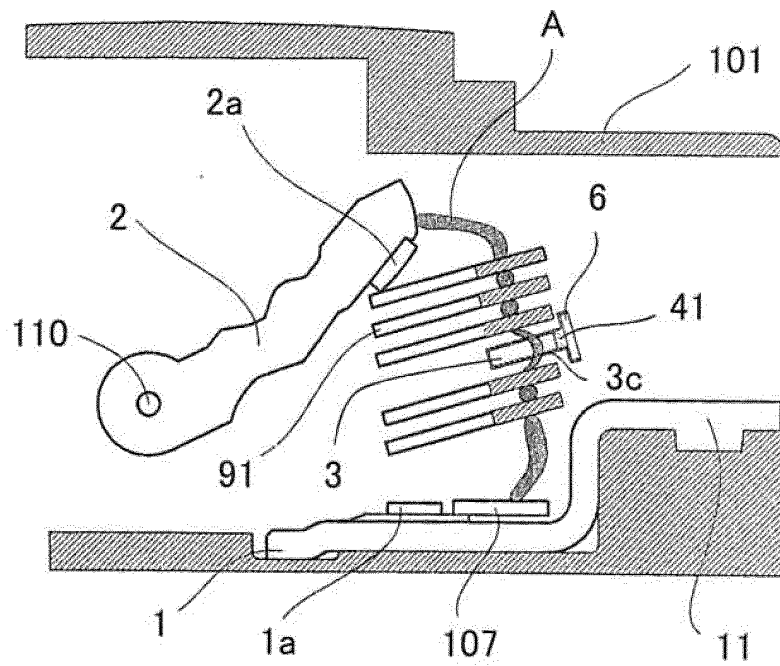


FIG. 35

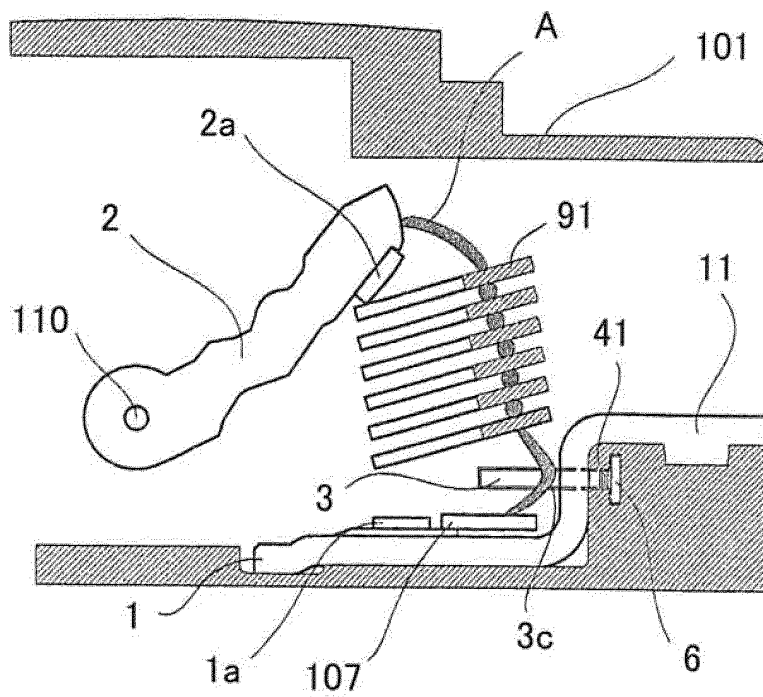




FIG. 36

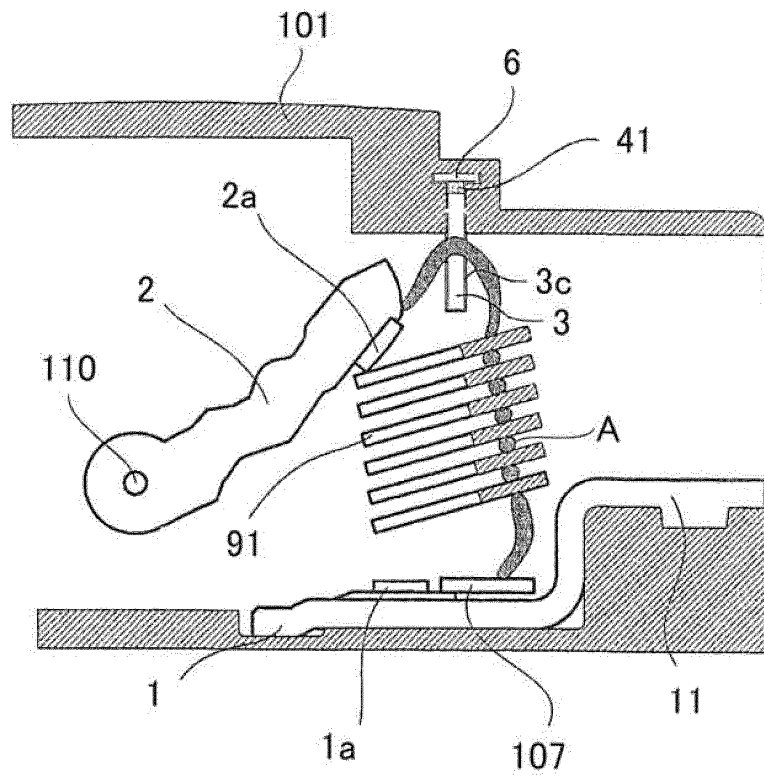


FIG. 37

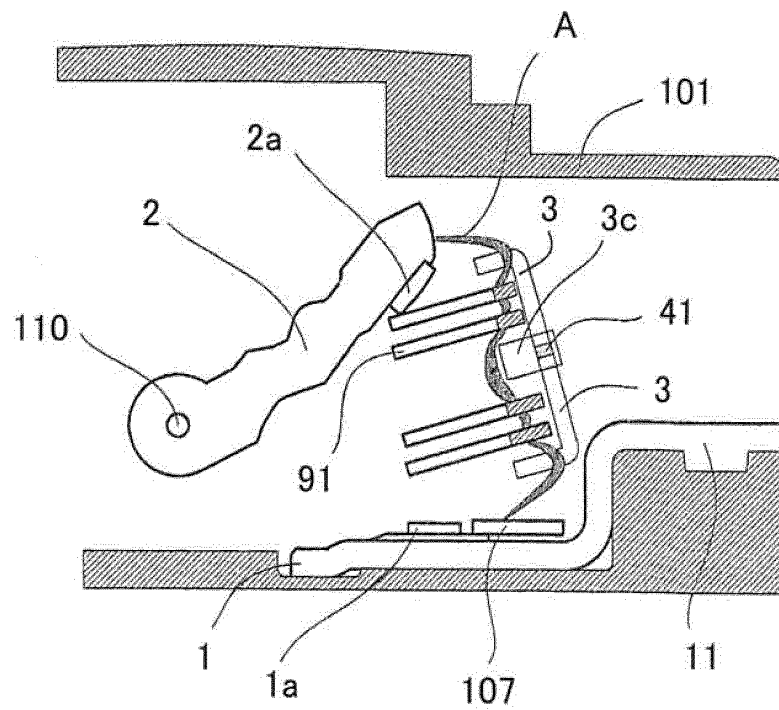


FIG. 38

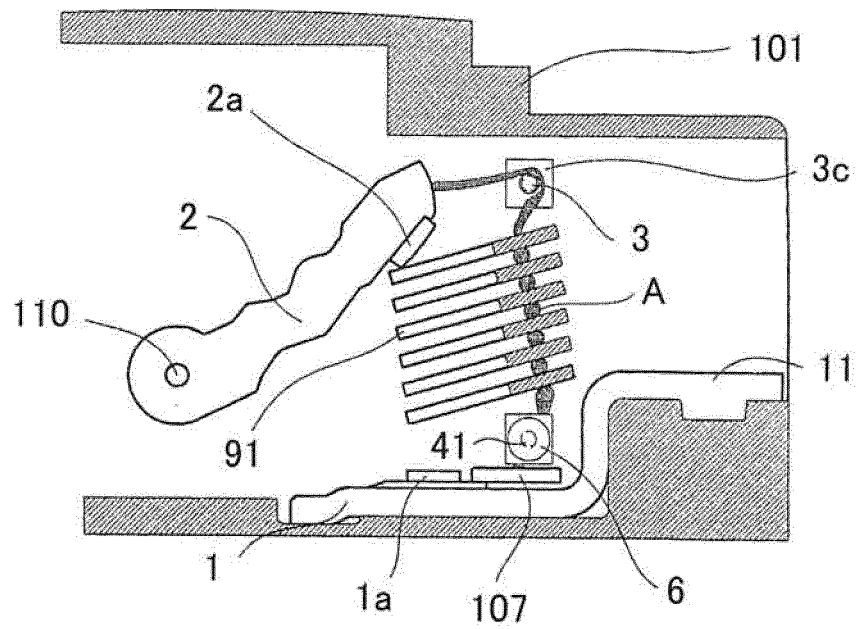


FIG. 39

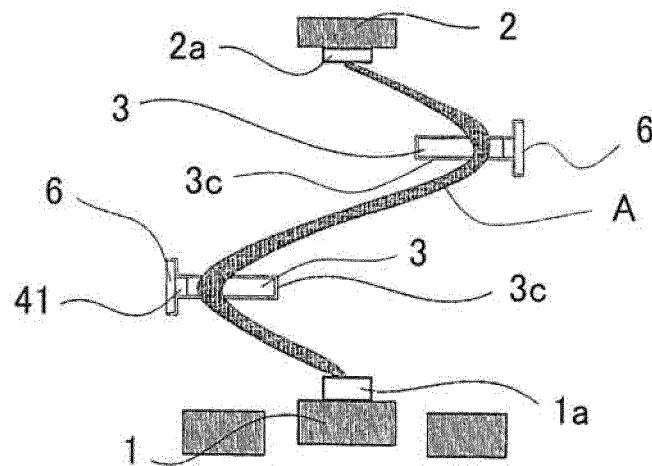


FIG. 40

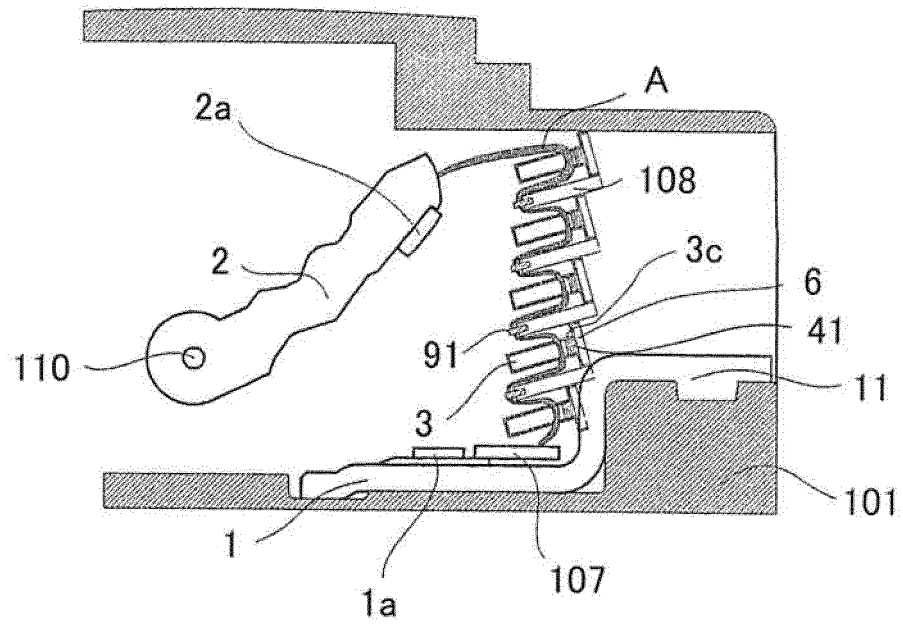


FIG. 41

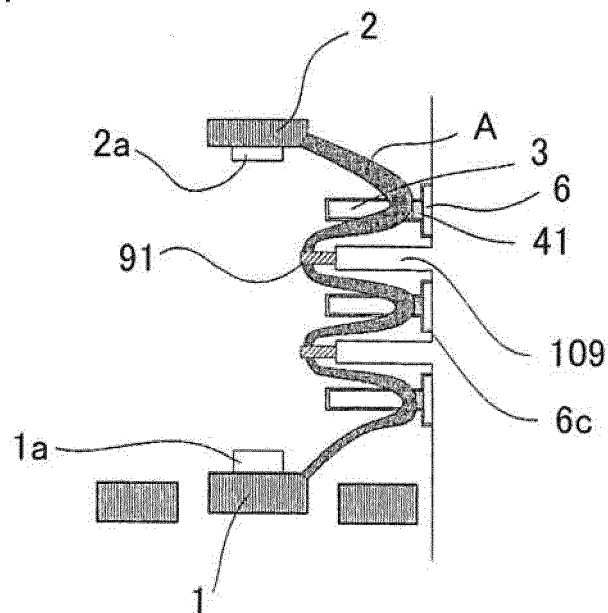


FIG. 42

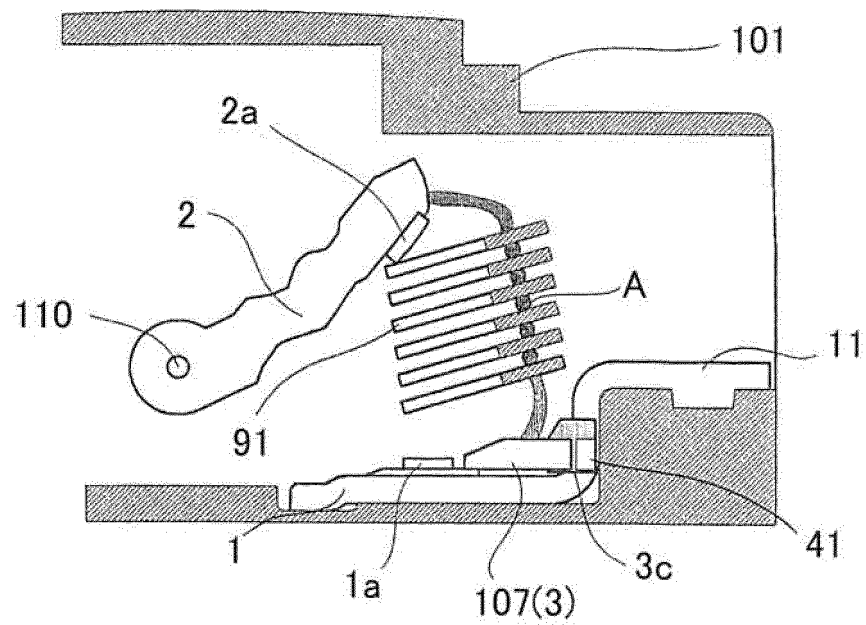


FIG. 43

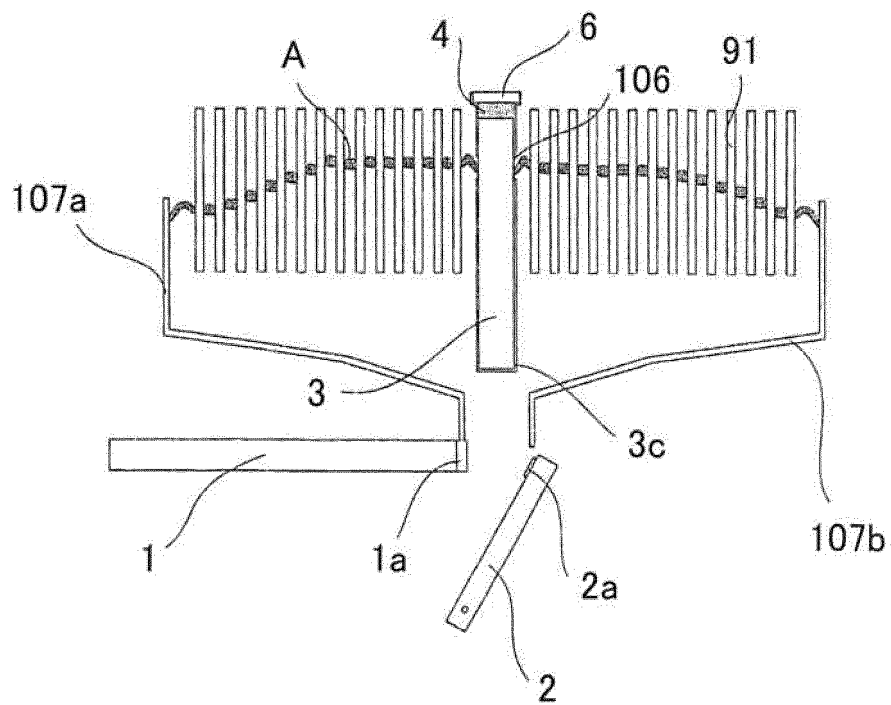
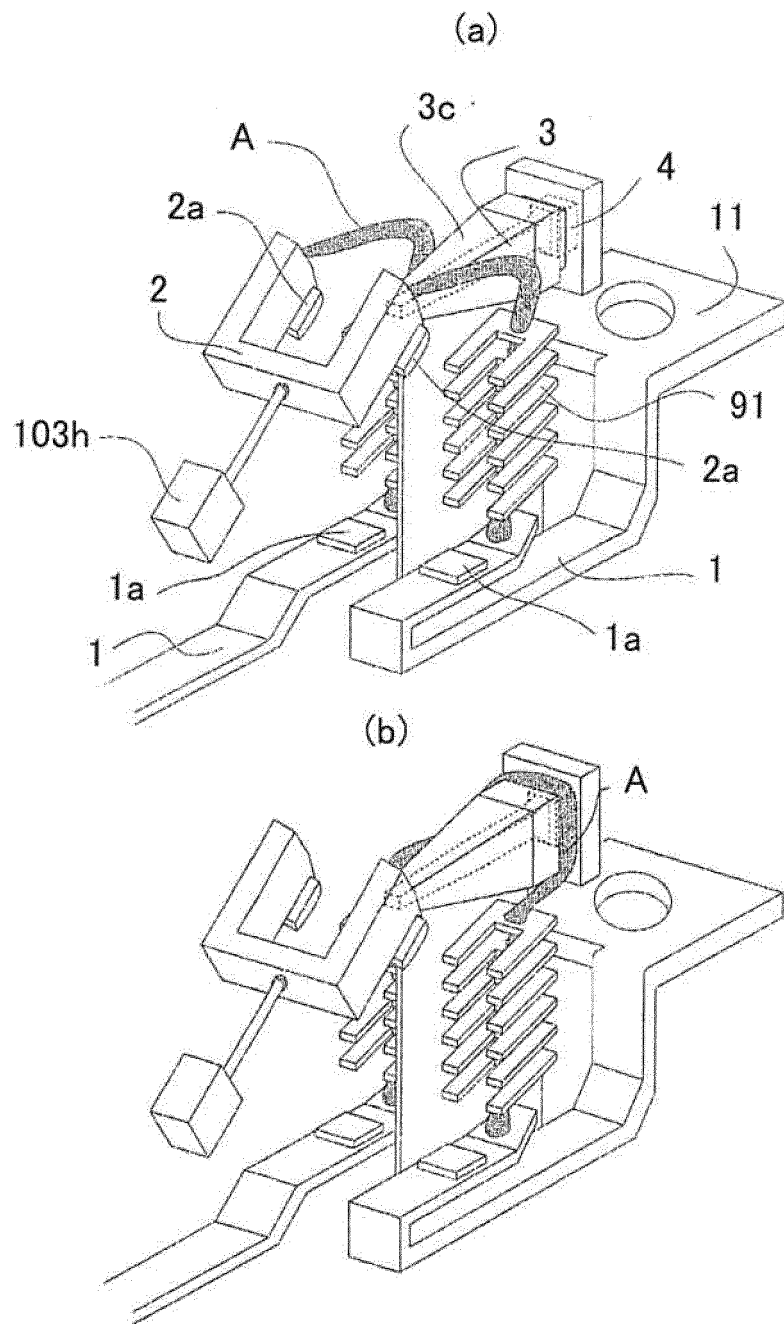


FIG. 44



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/084204

## A. CLASSIFICATION OF SUBJECT MATTER

H01H9/44(2006.01)i, H01H50/00(2006.01)i, H01H73/18(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01H9/44, H01H50/00, H01H73/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2014

Kokai Jitsuyo Shinan Koho 1971-2014 Toroku Jitsuyo Shinan Koho 1994-2014

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 39-028834 B1 (Siemens-Schuckertwerke AG.),	31
A	12 December 1963 (12.12.1963), entire text; all drawings (Family: none)	32
A	JP 53-089980 A (Hitachi, Ltd.), 08 August 1978 (08.08.1978), entire text; fig. 2 to 5 (Family: none)	1-30
A	JP 11-040029 A (Daiichi Denki Kabushiki Kaisha), 12 February 1999 (12.02.1999), entire text; all drawings (Family: none)	1-31

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&amp;" document member of the same patent family

Date of the actual completion of the international search  
24 March, 2014 (24.03.14)Date of mailing of the international search report  
01 April, 2014 (01.04.14)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/084204

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 087202/1985 (Laid-open No. 202841/1986) (Fuji Electric Co., Ltd.), 19 December 1986 (19.12.1986), fig. 1 to 5 (Family: none)	1
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 136278/1989 (Laid-open No. 082542/1991) (Fuji Electric Co., Ltd.), 22 August 1991 (22.08.1991), entire text; all drawings (Family: none)	13-15
A	JP 2012-199137 A (Panasonic Corp.), 18 October 2012 (18.10.2012), fig. 1 to 3 (Family: none)	33

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## INTERNATIONAL SEARCH REPORT

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With respect to claim 4:

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"One end of the magnetic body" seems to be mistakenly written as "the other end of the magnetic body" in the description that "a coil-shaped conductor is wound around the other end of the magnetic body to constitute at least part of the magnetic body as a first electromagnet of the magnet" in claim 4.

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More specifically, embodiment 14 is considered to correspond to claim 4, but in fig. 17 showing embodiment 14, a coil-shaped conductor is wound around the end on the permanent magnet side of the magnetic body.

Since claim 1 to which claim 4 refers describes "a long magnetic body having one end that is in contact with a magnetic pole face of the magnet" and "the other end of the magnetic body being disposed so as to be close to an arc generation region between the fixed contact and the movable contact", "one end" is considered to correspond to the end on the permanent magnet side of the magnetic body around which the coil-shaped conductor is wound.

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(Meanwhile, pay attention to a point such that similar statement is also present in paragraph [0044].)

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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 2009087918 A [0003]