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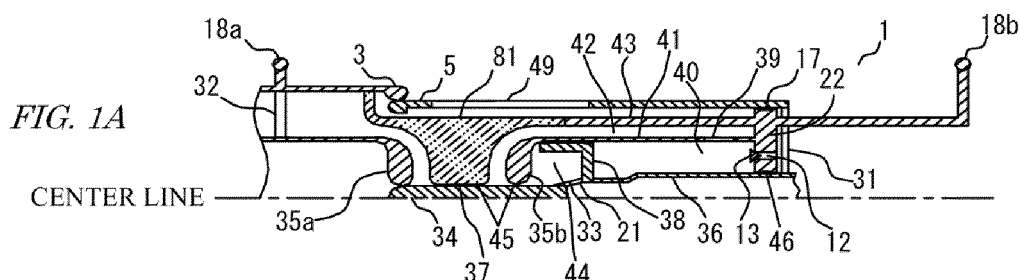
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(54) **GAS CIRCUIT-BREAKER**

(57) A reduction of the temperature of a blown gas, an improvement of a durability and a reduction of a maintenance frequency, a reduction of a current cutoff time, a reduction of drive and actuation energy, and a stabilization of a gas flow are accomplished. A pair of stationary arc electrodes 35a, 35b is disposed in a sealed container filled with an arc-extinguishing gas 1 to face with each other. A trigger electrode 34 in a rod shape with a smaller diameter is disposed between the stationary arc electrodes 35a, 35b so as to be freely movable. An insulation

nozzle 81 is disposed so as to surround the trigger electrode 34. An accumulating chamber 42 to reserve the arc-extinguishing gas 1 having undergone pressure increase is provided, and a switch causing the accumulating chamber 42 to be in a closed state or a released state is provided. The switch includes gaps between the arc electrode 35b and the trigger electrode 34, and between the insulation nozzle 81 and the trigger electrode 34, and by closing the gaps by the moved trigger electrode 34, a closing component 45 is formed.



DescriptionFIELD

5 **[0001]** Embodiments of the present disclosure relate to a gas circuit breaker that includes an accumulating space for an arc-extinguishing gas.

BACKGROUND

10 **[0002]** In power systems, in general, a gas circuit breaker is applied to break currents including an excessive fault current. As for a type of gas circuit breakers, a puffer-type gas circuit breaker that blows an arc-extinguishing gas to extinguish an arc discharging has become popular (see, for example, Patent Document 1). A puffer-type gas circuit breaker will be explained in detail with reference to FIGs. 7A-7C. FIGs. 7A-7C illustrate a rotationally symmetric shape around a center line as a rotational axis, and FIG. 7A illustrates a current-flowing state, FIG. 7B illustrates a first half stage of a current break action, and, FIG. 7C illustrates a latter half stage of the current break action.

15 **[0003]** As illustrated in FIGs. 7A-7C, a puffer-type gas circuit breaker is provided with an opposing arc electrode 2 and an opposing current-flowing electrode 3, and a movable arc electrode 4 and a movable current-flowing electrode 5 are disposed on the same axes as those of the electrodes 2, 3 to face the electrode 2, 3 and are capable of freely reciprocate. Those electrodes 2-5 are placed in a sealed container (unillustrated) filled with an arc-extinguishing gas 1. In these
20 electrodes, the arc electrodes 2, 4 that form a pair are capable of electrically flowing a current, and when the current break action is performed by the gas circuit breaker, an arc discharge 7 is produced between both electrodes 2, 4. The arc-extinguishing gas 1 filled in the sealed container (unillustrated) is normally an SF₆ gas (sulfur hexafluoride gas) that has excellent arc breaking performance (arc extinguishing performance) and electrical insulation performance, however other media are also applicable.

25 **[0004]** The movable arc electrode 4 is attached to the tip of a hollow drive rod 6, and the movable current-flowing electrode 5 is attached to the tip of a puffer cylinder 9. In addition, an insulation nozzle 8 is also attached inside the movable current flowing electrode 5 on the tip of the puffer cylinder 9. The movable arc electrode 4, the movable current-flowing electrode 5, the drive rod 6, the insulation nozzle 8, and the puffer cylinder 9 are formed integrally. This integral part is driven together with the movable electrodes 4, 5, thus collectively referred to as a movable component.

30 **[0005]** The movable component is driven by an unillustrated drive device. In addition, a stationary piston 11 is placed in the puffer cylinder 9 so as to be relatively slidable to such piston. The stationary piston 11 is fixed in the sealed space to be independent from the movable component. The stationary piston 11 is provided with an intake port 12 and an intake valve 13.

35 **[0006]** The opposing arc electrode 2 and the opposing current-flowing electrode 3 are formed integrally by a rib 20 formed of a conductive metal, and electrically connected to a terminal 18a. On the other hand, the movable arc electrode 4 and the movable current-flowing electrode 5 are also formed integrally by a link 19 formed of a conductive metal, and are electrically connected to a terminal 18b via a slide contact 17.

40 **[0007]** A puffer chamber 16 is formed by a space surrounded by the drive rod 6, the puffer cylinder 9, and the stationary piston 11. The puffer cylinder 9 and the stationary piston 11 serve to increase the pressure of the arc-extinguishing gas 1 in the puffer chamber 16, while the puffer chamber 16 serves as an accumulating space that reserves the arc-extinguishing gas 1 that have undergone the pressure increase. The insulation nozzle 8 serves to adjust and blow the flow of the arc-extinguishing gas 1 toward the arc discharge 7. As illustrated in FIG. 7B, when the opposing arc electrode 2 and the movable arc electrode 4 which have been in contact with each other are disconnected, the arc discharge 7 is produced therebetween.

45 **[0008]** According to the puffer-type gas circuit breaker employing the above structure, in the closing state, the arc electrode 2 and the opposing current flowing electrode 3 are in contact with the movable arc electrode 4 and the movable current-flowing electrode 5, respectively, and thus a current-flowing state is obtained (see FIG. 7A). When a current break action is performed from this current-flowing state, the movable arc electrode 4 and the movable current-flowing electrode 5 are driven by the drive rod 6 toward the right side in FIGs. 7A-7C.

50 **[0009]** When the drive by the drive rod 6 advances, and the opposing arc electrode 2 and the movable arc electrode 4 are disconnected, the arc discharge 7 is produced between the arc electrodes 2, 4. Simultaneously, with the current break action, the puffer cylinder 9 and the stationary piston 11 come close relatively to each other, the volume in the puffer chamber 16 decreases, and thus the arc-extinguishing gas 1 is mechanically compressed (see FIG. 7B).

55 **[0010]** Also, simultaneously, a heat exhaust gas 14 produced by the heat of the high-temperature arc discharge 7 is captured in the puffer chamber 16, and thus a pressure-increase effect by the arc heat can also be expected (see FIG. 7B) along with the mechanical compression explained above. This will be referred to as a self-pressure-increase action. The insulation nozzle 8 adjusts the flow of the arc-extinguishing gas 1 compressed in the puffer chamber 16, blows the arc-extinguishing gas 1 as a blown gas 15a to the arc discharge 7, thereby extinguishing the arc discharge 7 (see FIG.

7C). At this time, since the blown gas 15a is heated by the heat exhaust gas 14 from the arc discharge 7, this gas will be referred to as a high-temperature blown gas 15a hereafter.

[0011] On the other hand, when the puffer-type gas circuit breaker performs an making action, at a timing when the pressure inside the puffer chamber 16 becomes lower than the filling pressure of the arc-extinguishing gas 1, the intake valve 13 provided at the stationary piston 11 is actuated to open the intake port 12, and thus the arc-extinguishing gas 1 is supplementary provided to the puffer chamber 16. Hence, at the time of loading action immediately after the current break action, the arc-extinguishing gas 1 is quickly taken in the puffer chamber 16. Hence, even when the puffer-type gas circuit breaker performs a fast-speed circuit re-closing action, the sufficient gas flow rate of the high-temperature blown gas 15a is ensured at the time of the second current break action, thereby surely extinguishing the arc discharge 7.

CITATION LIST

PATENT LITERATURES

[0012] Patent Document 1: JPH07-109744 A

[0013] However, conventional gas circuit breakers explained above have the following technical problems.

(A) Blown Gas Temperature

[0014] At the time of current break action by conventional gas circuit breakers, since the high-temperature blown gas 15a has been heated by the heat exhaust gas 14 from the arc discharge 7, the blown gas would inevitably be at high-temperature state. This may reduce the cooling efficiency for the arc discharge 7, reducing the current breaking performance.

(B) Adverse Effect to Durability and Maintenance of Blown Gas Temperature

[0015] In addition, by blowing the high-temperature blown gas 15a that is at high temperature to the arc discharge 7, the surrounding temperature around the arc discharge 7 further rises. Consequently, the arc electrodes 2, 4 and the insulation nozzle 8 are exposed under the high temperature environment to deteriorate easily. Hence, a frequent maintenance is needed. This opposes user's needs to improve the durability and to reduce of maintenance.

(C) Current Breaking Time

[0016] Still further, since the pressure inside the puffer chamber 16 is increased also by the self-pressure-increase action, it is necessary to capture the heat exhaust gas 14 in the puffer chamber 16, but in order to capture the heat exhaust gas 14 in, a certain amount of time is needed. Hence, a time to complete the current breaking action may become long. Since the gas circuit breaker is a device to promptly break an excessive fault current, in terms of the basic performance of the gas circuit breaker, there is always a demand to reduce the time to complete the current breaking.

(D) Drive and Actuation Energy

[0017] In addition, it is important to reduce the drive and actuation energy in the actuation mechanism of the movable component in order to reduce the costs of a gas circuit breaker. In order to reduce the drive and actuation energy in a gas circuit breaker, it is important to achieve a weight reduction of the movable component.

[0018] According to conventional puffer-type gas circuit breakers, however, since the large-size puffer cylinder 9, the insulation nozzle 8, the movable arc electrode 4, etc., are all included in the movable component, reduction of the weight thereof has a limit. In puffer-type gas circuit breakers that have a heavy movable component, in order to obtain a necessary opening and disconnecting speed to break the current, large drive and actuation energy is inevitably needed.

[0019] Still further, since the heat exhaust gas 14 flows into the puffer chamber 16, excessive pressure as a compression and drive repulsion force may be applied to the stationary piston 11 depending on the break current condition. Hence, in order to get over this compression and drive repulsion force, a large drive and actuation energy may be needed. Hence, conventional gas circuit breakers need a large drive and actuation energy in some cases as explained above.

(E) Gas Flow Instability

[0020] Yet still further, according to puffer-type gas circuit breakers that utilize the self-pressure-increase action, when the thermal energy of arc heat changes in accordance with the magnitude of a current to be broken and the phase condition of an AC current, the blowing force varies. That is, since the arc heat is utilized for increasing the pressure of

the arc-extinguishing gas 1, the arc heat itself affects the arc-extinguishing performance. Consequently, when the magnitude of the current to be broken and the phase condition of the AC current change, the blowing force also changes, failing to always obtain stable flow of the high-temperature blown gas 15a.

[0021] Embodiments of the present disclosure have been proposed in order to address the foregoing technical problems. That is, a gas circuit breaker according to an embodiment is to achieve a temperature reduction of a blown gas, an improvement of a durability, and a reduction of a maintenance frequency, a reduction of a current breaking time, a reduction of drive and actuation energy, and a stabilization of a gas flow.

[0022] In order to achieve the above objective, a gas circuit breaker includes:

a pair of arc electrode disposed in a sealed container filled with an arc-extinguishing gas facing each other, the arc electrodes being capable of electrically flowing a current, an arc discharge being produced between both electrodes at a time of current breaking action, an arc extinguishing gas produced by the arc discharge;
a pressure increaser increasing a pressure of the arc-extinguishing gas to produce a pressure-increased gas in order to blow the arc-extinguishing gas to the arc discharge;
an accumulating space reserving the pressure-increased gas;
an insulation nozzle delivering the pressure-increased gas toward the arc discharge from the accumulating space;
switchThis gas circuit breaker has the following features.

[0023]

(1) A switch to release or close the accumulating space to be in a closed state or a released state, and a trigger electrode disposed between the arc electrodes freely movable therebetween, and producing the arc discharge along with a movement.

(2) The switch includes a gap between the arc electrode and the trigger electrode, a gap between the insulation nozzle and the trigger electrode, or both of the gaps.

BRIEF DESCRIPTION OF DRAWINGS

[0024]

FIGs. 1A-1E are each cross-sectional views illustrating a structure according to a first embodiment;
FIG. 2 is a cross-sectional view orthogonal to a center line illustrating an arrangement of a link 31 and a support 21 according to the first embodiment;
FIG. 3 is an enlarged cross-sectional view illustrating a structure around a pressure relief 47 according to the first embodiment;
FIG. 4 is a cross-sectional view illustrating a structure according to a second embodiment;
FIG. 5 is a diagram illustrating a change in stroke relating to compression repulsion force and movable-component acceleration in the case of a flat drive and output characteristic;
FIG. 6 is a diagram illustrating a change in stroke relating to compression repulsion force and movable-component acceleration in the case of a monotonic decrease drive and output characteristic; and
FIGs. 7A-7C are diagrams illustrating a structure of a conventional puffer-type gas circuit breaker.

DETAILED DESCRIPTION

(1) First Embodiment

(Structure)

[0025] A structure according to a first embodiment of the present disclosure will be explained with reference to FIGs. 1A-3. The major components in the first embodiment are similar to those of a conventional gas circuit breaker illustrated in FIGs. 7A-7C. Hence, the same component as that of the conventional gas circuit breaker illustrated in FIG. 7 will be denoted by the same reference numeral, and the duplicated explanation thereof will be omitted. FIGs. 1A-1E illustrate a rotationally symmetric shape around a rotation axis that is the center line, like FIGs. 7A-7C. FIG. 1A illustrates a current-flowing state, FIG. 1B illustrates a first half stage of a current breaking action, FIGs. 1C, 1D illustrate a latter half stage of the current breaking action, and FIG. 1E illustrates a state after the current breaking action is completed.

(Stationary Arc Electrode)

[0026] In the first embodiment, the gas pressure in an unillustrated sealed container is the filling pressure of the arc-extinguishing gas 1 at any sites in a normal actuation condition. In the first embodiment, a stationary arc electrode 35a is provided instead of the opposing arc electrode 2, and a stationary arc electrode 35b is disposed facing the stationary arc electrode 35a. The arc electrodes 35a, 35b are capable of electrically flowing a current, and at the time of current breaking action, the arc discharge 7 is produced between both electrodes 35a, 35b, and the heat exhaust gas 14 is produced by the heat of the arc discharge 7.

[0027] The pair of arc electrodes 35a, 35b is not components of a movable component including the movable current-flowing electrode 5, etc., but is a pair of electrodes fixed inside the sealed container (unillustrated). The arc electrode 35a and the opposing current-flowing electrode 3 are formed integrally by a rib 32 formed of a conductive metal, and are connected to a terminal 18a.

(Trigger Electrode)

[0028] A trigger electrode 34 in a rod shape having a smaller diameter than those of the stationary electrodes 35a, 35b is disposed inwardly the stationary arc electrodes 35a, 35b to move therebetween in the center line direction while being in contact with the stationary arc electrodes 35a, 35b. However, as long as the trigger electrode 34 is always electrically connected to the stationary arc electrode 35b, the movable current-flowing electrode 5, and a terminal 18b, it is unnecessary that the trigger electrode 34 is always in contact with the stationary arc electrode 35b.

[0029] In the current-flowing state, the trigger electrode 34 contacts with the stationary arc electrode 35a, thereby achieve the current-flowing state. In addition, at the time of current break, the arc discharge 7 is produced between the trigger electrode 34 and the stationary arc electrode 35a, and is eventually transferred to the stationary arc electrode 35b from the trigger electrode 34. That is, the actuation of the trigger electrode 34 ignites an arc between the stationary arc electrodes 35a, 35b.

[0030] Such trigger electrode 34 is one of featuring components in the embodiment, and when the current breaking is completed, gaps are formed between the stationary arc electrode 35b and the trigger electrode 34, and between a nozzle throat 37 of an insulation nozzle 81 to be explained later and the trigger electrode 34 (see FIGs. 1D, 1E). The gaps form an switch that causes an accumulating chamber 42 to be released in terms of pressure.

[0031] In addition, when the trigger electrode 34 is inserted to the stationary arc electrode 35b and the nozzle throat 37 of the insulation nozzle 81, the gaps would be in a closed state. Portions that make the gaps closed will be referred to as a closing component 45 (see FIGs. 1A and 1B). The closed portion makes an accumulating chamber 42 to be in closed state when the trigger electrode 34 moves and forms the closing component 45 to make the gap portion to be in closed state. Still further, when the trigger electrode 34 is moved in the opposite direction, the closing component 45 is opened, and the gaps are opened, the switch causes the accumulating chamber 42 to be in a released state in terms of pressure.

(Accumulating chamber)

[0032] The accumulating chamber 42 is an accumulating space to reserve the pressure-increased gas. The pressure-increased gas is the arc-extinguishing gas 1 having undergone pressure increase, and is produced by a pressure-increase-chamber cylinder 41 and a movable piston 38 (to be explained later), which form a pressure increaser. The accumulating chamber 42 is formed so as to be surrounded by an accumulating-chamber cylinder 43, a pressure-increase-chamber cylinder 41, the stationary arc electrode 35b, the insulation nozzle 81, and a flange 22. The accumulating-chamber cylinder 43 and the pressure-increase-chamber cylinder 41 are integrally attached to the flange 22.

[0033] The accumulating chamber 42 has, as a whole, an L-shaped space (U-shape as a whole) that is a half cross-section relative to the center line. The accumulating-chamber cylinder 43 is disposed at the upper-surface side of the accumulating chamber 42 among the three long sides in the L-shape, the accumulating-chamber cylinder 41 is disposed at the lower-surface side of the accumulating chamber 42, and the flange 22 is disposed at the right-surface side of the accumulating chamber 42. In addition, at the short side of the L-shape, the stationary arc electrode 35b and the insulation nozzle 81 face with each other, the stationary arc electrode 35b is disposed at the right-surface side of the accumulating chamber 42, and the insulation nozzle 81 is disposed at the left-surface side of the accumulating chamber 42.

(Relationship between Accumulating Chamber and Switch)

[0034] As explained above, the switch causes the accumulating chamber 42 to be in the closed state or the released state in accordance with the actuation of the trigger electrode 34. More specifically, at the first half stage of the current breaking action, the trigger electrode 34 seals the flow channel in the nozzle throat 37 and the stationary arc electrode

35b to form the closing component 45, thereby causing the accumulating chamber 42 to be in the closed state. Hence, the flow-in of the heat exhaust gas 14 produced by the heat of the arc discharge 7 to the interior of the accumulating chamber 42 is restricted. In addition, the flow-out of the pressure-increased gas from the accumulating chamber 42 is also restricted.

[0035] At the latter half stage of the current breaking action, the movement of the trigger electrode 34 transfers the arc discharge 7 from the trigger electrode 34 to the stationary arc electrode 35b, and the flow-channel sealing of the nozzle throat 37 and the stationary arc electrode 35b are canceled. That is, the gaps are formed between the stationary arc electrode 35b and the trigger electrode 34, and between the nozzle throat 37 and the trigger electrode 34, and thus the accumulating chamber 42 would be in the released state in terms of pressure. The accumulating chamber 42 that has become the released state causes the pressure-increased gas in the accumulating chamber 42 to be delivered to the arc discharge 7 through the insulation nozzle 81.

(Movable Component)

[0036] The trigger electrode 34 and the movable current-flowing electrode 5 are integrally provided with the support 21, the movable piston 38, a drive rod 36, and a link 31 all formed of a conductive metal, and these components form the movable component. A heat dissipation hole 49 is provided in the movable current-flowing electrode 5 so as to ensure the required current-flowing capacity. The heat dissipation hole 49 is to dissipate heat generated at the contacting and current-flowing portion between the movable current-flowing electrode 5 and the opposing current-flowing electrode 3.

[0037] In addition, the movable component is always electrically connected to the stationary arc electrode 35b and the terminal 18b via the slide contact 17. Hence, an very small gap is provided between the trigger electrode 34 and the stationary arc electrode 35b, and thus the production of metal wear powders that adversely effects the electrical insulation performance by sliding are not to be produced.

(Insulation Nozzle)

[0038] The insulation nozzle 18 is disposed so as to surround the trigger electrode 34. The insulation nozzle 81, like the insulation nozzle 8 of a conventional gas circuit breaker illustrated in FIGs. 7A-7C, delivers the arc-extinguishing gas 1 having undergone pressure increase from the accumulating chamber 42 to the arc discharge 7. However, the insulation nozzle 81 is formed so as to blow the arc-extinguishing gas 1 to the arc discharge 7 substantially vertically from the surrounding of the arc discharge 7 toward the center thereof.

[0039] The insulation nozzle 81 is an immobilized component that does not move at the time of current breaking action. That is, the insulation nozzle 81 is fixed not to the movable-component side but in the sealed container. This is the difference from the conventional insulation nozzle 8 illustrated in FIG. 7. In addition, at the time of current breaking action, the trigger electrode 34 moves inside the insulation nozzle 81. Hence, the arc discharge 7 is produced inside the insulation nozzle 81.

[0040] The insulation nozzle 81 is formed with the nozzle throat 37 that is defined as the minimum cross-sectional area of the gas flow channel inside the insulation nozzle 81. Both open ends of the nozzle throat 37 have increased diameters, and thus the cross-sectional area becomes widespread. In this case, since both open ends of the nozzle throat 37 have increased diameters, the flow channel area for the gas flowing in from the exterior of the arc discharge 7 is designed to be larger than the total cross-sectional area of the internal diameter part of the nozzle throat 37 and that of the stationary arc electrode 35b.

(Pressure Increase Chamber)

[0041] The space surrounded by the pressure-increase-chamber cylinder 41, the drive rod 36, the movable piston 38, and the flange 22 is defined as the pressure increase chamber 40. The pressure-increase-chamber cylinder 41 is disposed at the upper-surface side of the pressure increase chamber 40, the drive rod 36 is disposed at the lower-surface side of the pressure increase chamber 40, the movable piston 38 is disposed at the left-surface side of the pressure increase chamber 40, and the flange 22 is disposed at the right-surface side of the pressure increase chamber 40.

[0042] Hence, when the movable piston 38 reciprocates, the lower end of the flange 22 and the upper end of the movable piston 38 slide over the outer circumference of the drive rod 36 and the inner circumference of the pressure-increase-chamber cylinder 41, respectively. However, since a pressure relief 47 to be explained later is provided in the outer circumference of the drive rod 36, when the lower end of the flange 22 is located at this site, a gap is formed therebetween. In addition, the flange 22 is formed with the intake port 12, and the intake valve 13 is attached to the intake port 12. The intake valve 13 sucks and supplementary supplies the arc-extinguishing gas 1 in the pressure increase chamber 40 only when the pressure inside the pressure increase chamber 40 becomes lower than the filling pressure inside the sealed container.

[0043] The movable piston 38 is driven by together with the trigger electrode 34, the support 21, the drive rod 36, the link 31, and the movable current-flowing electrode 5, etc. by an unillustrated drive device. Among these components, the pluralities of supports 21 and links 31 are provided at a pitch predetermined angle by predetermined angle around the center line so as to suppress an excessive concentration of mechanical force causing an axial displacement (see FIG. 2). Sealing members 46 are provided at the sliding portions of the drive rod 36 and movable piston 38 so as to suppress a pressure leakage from the pressure increase chamber 40, thereby achieving a gas-tightness.

[0044] The movable piston 38 moves apart from the arc discharge 7, and thus the arc-extinguishing gas 1 in the pressure increase chamber 40 is compressed and the pressure-increased gas is produced. That is, unlike a conventional extinguishing chamber, the movable piston 38 compresses the arc-extinguishing gas 1 at the back surface of the piston. Such movable piston 38 and the pressure-increase-chamber cylinder 41 form a pressure increaser. In addition, as illustrated in FIG. 3, the drive rod 36 is provided with the pressure relief 47 by, for example, partially decreasing the rod diameter or providing a pressure relief groove. The pressure relief 47 is to discharge the arc-extinguishing gas 1 in the pressure increase chamber 40 to the exterior as a discharge compression gas 48.

[0045] The pressure-increase-chamber cylinder 41 is formed with a communication hole 39, and the pressure increase chamber 40 is in communication with the accumulating chamber 42 via this communication hole 39 in terms of pressure in, at least at the first half stage of the current breaking procedure. In the latter half stage of the current breaking procedure, the communication hole 39 is blocked by the sealing members 46 provided on the outer circumference of the moving movable piston 38, and the pressure increase chamber 40 is isolated from the accumulating chamber 42 in terms of pressure.

(Heat Exhaust Gas Reserving Chamber)

[0046] With the pressure increase chamber 40 being disposed at the right side of the movable piston 38, a heat exhaust gas reserving chamber 44 that temporarily reserves the heat exhaust gas 14 is disposed at the left side of the movable piston 38, at a side nearer to a space where the arc discharge 7 is produced than the pressure increase chamber 40. The heat exhaust gas reserving chamber 44 is a space surrounded by the pressure-increase-chamber cylinder 41, the stationary arc electrode 35b, the trigger electrode 34, and the movable piston 38. The pressure in the heat exhaust gas reserving chamber 44 acts as assist force for the compression of the arc-extinguishing gas 1 by the movable piston 38 and by the pressure-increase-chamber cylinder 41.

[0047] An explanation will be given of a current breaking action according to the embodiment that employs the above structure.

<First Half Stage of Current Breaking Procedure (From FIG. 1A to FIG. 1B)>

[0048] When the trigger electrode 34 is opened and disconnected from the stationary arc electrode 35a, simultaneously, the arc discharge 7 is produced therebetween. The heat exhaust gas 14 produced from the arc discharge 7 flows in the direction apart from the arc discharge 7 simultaneously with the production of the arc discharge 7, and is quickly discharged to the space inside the sealed container.

[0049] In the first half stage of the current breaking procedure, the trigger electrode 34 blocks the nozzle throat 37 in the insulation nozzle 81 and the stationary electrode 35b, and thus the closing component 45 is formed. In addition, the pressure increase chamber 40 and the accumulating chamber 42 are in communication with each other via the communication hole 39, thus forming an integrated space. Hence, the arc-extinguishing gas 1 present in the sealed space consisting of the pressure increase chamber 40 and the accumulating chamber 42 is compressed by the movable piston 38, and is subjected to the pressure increase.

[0050] At this time, the closing component 45 restricts the flow-in of the heat exhaust gas 14 from the arc discharge 7 to the sealed space defined by the pressure increase chamber 40 and the accumulating chamber 42, and also restricts the flow-out of the arc-extinguishing gas 1 that is being subjected to pressure increase in such a sealed space. Hence, except a quite small gap in the closing component 45 that is inevitable in terms of structure, the energy needed for the compression by the movable piston 38 is substantially completely converted to the pressure energy by the arc-extinguishing gas 1 in the sealed space (pressure increase chamber 40 and accumulating chamber 42). In addition, within a quite short time during the current breaking action, the heat from the arc discharge 7 hardly affects. Therefore, the pressure increase of the arc-extinguishing gas 1 in the sealed space (pressure increase chamber 40 and accumulating chamber 42) is achieved only through the thermal insulation compression action by the movable piston 38.

<Latter Half Stage of Current Breaking Procedure (From FIG. 1C to FIG. 1D)>

[0051] In the latter half stage of the current breaking procedure, the volume of the pressure increase chamber 40 relatively decreases together with the movement of the movable piston 38, and most of the arc-extinguishing gas 1

compressed by the movable piston 38 is reserved in the accumulating chamber 42. Simultaneously, as illustrated in FIG. 3, the sealing members 46 provided on the outer circumference of the movable piston 38 block the communication hole 39. Hence, the pressure increase chamber 40 and the accumulating chamber 42 are isolated from each other in terms of pressure. In addition, in conjunction with this action, the pressure relief 47 is released. Hence, the arc-extinguishing gas 1 in the pressure increase chamber 40 is discharged to the exterior as the discharge compression gas 48, and the pressure in the pressure increase chamber 40 is released to the interior of the sealed space.

[0052] On the other hand, by the trigger electrode 34 passing through the nozzle throat 37 of the insulation nozzle 81 and the stationary arc electrode 35b, the closing component 45 is released. Hence, the insulation nozzle 81 powerfully blows a low-temperature blown gas 15b that has a low temperature toward the arc discharge 7 from the accumulating chamber 42. At this time, the low-temperature blown gas 15b is blown to the arc discharge 7 so as to traverse substantially vertically toward the center around the arc discharge 7. Accordingly, the arc discharge 7 is rapidly cooled at the blowing point at which the gas is blown.

[0053] The insulation nozzle 81 blows the low-temperature blown gas 15b to the arc discharge 7, and adjusts, as appropriate, the flow direction of the gas so as to smoothly discharge the heat exhaust gas 14. In particular, since the flow channel area from the exterior of the arc discharge 7 is designed so as to be larger than the total cross-sectional area of the internal diameter part of the nozzle throat 37 and that of the stationary arc electrode 35b which is the discharge area of the heat exhaust gas 14, the sufficient flow rate of the low-temperature blown gas 15b for cooling the arc discharge 7 is ensured. In the latter half stage of the current breaking procedure, the arc discharge 7 is transferred to the stationary arc electrode 35b. Hence, the time period at which the arc discharge 7 is igniting on the trigger electrode 34 is only the limited time period within the initial stage of the current break action, until the arc discharge 7 is transferred to the stationary arc electrode 35b.

[0054] In the stage illustrated in FIG. 1C, the trigger electrode 34 passes through the nozzle throat 37 of the insulation nozzle 81, releases only the closing component 45 out the nozzle-throat-37 side, and the blowing of the low-temperature gas 15b starts only at the left-side direction in the figure from the gap between the trigger electrode 34 and the nozzle throat 37 of the insulation nozzle 81. Immediately after, in FIG. 1D, the closing component 45 in the stationary arc electrode 35b is released together with the movement of the trigger electrode 34.

[0055] Hence, at the blowing point at which the low-temperature gas 15b is blown, by the powerful blow in both directions which are the left-side direction and the right-side direction in the figure, the arc discharge 7 is rapidly cooled. The heat exhaust gas 14 exhausted from the stationary-arc-electrode-35b side is delivered to the heat exhaust gas reserving chamber 44 formed at the opposite side of the compression chamber of the movable piston 38, and is exhausted to the sealed container via the exhaust opening 33.

<After Completion of Current Breaking Procedure>

[0056] The intake valve 13 provided at the pressure increase chamber 40 sucks and supplementary supplies the arc-extinguishing gas 1 to the pressure increase chamber 40 only when the pressure inside the pressure increase chamber 40 becomes lower than the filling pressure in the sealed container. Hence, after the current breaking procedure, when the making action is performed again, the fresh arc-extinguishing gas 1 is supplied from the sealed container to the pressure increase chamber 40 via the intake hole 12.

(Action and Effect)

[0057] The action and effect according to the above first embodiment are as follows.

(A) Reduction of the temperature of the blown gas

[0058] The first embodiment has a feature such that no self-pressure-increase action by the arc heat is utilized. The low-temperature blown gas 15b blown to the arc discharge 7 is not subjected to pressure increase in terms of heat by the heat exhaust gas 14, and is a gas that has been pressure increased only through the mechanical compression by the movable piston 38.

[0059] There is still a possibility that a quite small amount of heat exhaust gas 14 flows in the accumulating chamber 42 through the gap between the trigger electrode 34 and the nozzle throat 37, but the adverse effect thereof is quite little. Hence, the temperature of the low-temperature blown gas 15b to the arc discharge 7 is remarkably lower than that of the conventional high-temperature blown gas 15a that utilizes the self-pressure-increase action. By blowing such low-temperature blown gas 15b, the cooling effect of the arc discharge 7 is remarkably improved.

(B) Improvement of the durability and reduction of the maintenance frequency

[0060] According to the embodiment, the temperature around the arc discharge 7 is reduced by blowing the low-temperature gas 15b thereto. Hence, in comparison with a case in which the stationary arc electrodes 35a, 35b and the insulation nozzle 81 are exposed under a high-temperature environment due to the current break, the deterioration of those components is remarkably reduced, and thus the durability of the components are improved. Hence, the maintenance frequency of the stationary arc electrodes 35a, 35b and the insulation nozzle 81 are reduced, and thus a load of maintenance is reduced.

[0061] In addition, the arc electrodes 35a, 35b fixed at the sealed-container side do not affect the weight of the movable component that includes the movable piston 38, etc. Hence, the stationary arc electrodes 35a, 35b may be thickened without a concern for an increase in weight. Consequently, the durability of the arc electrodes 35a, 35b against a large current arc is remarkably improved.

[0062] Still further, when the arc electrodes 35a, 35b are thickened, the electric field concentration at the respective tips of the arc electrodes 35a, 35b upon an application of a high voltage across the electrode gap are remarkably eased. Hence, in comparison with conventional gas circuit breakers, the necessary gap clearance is reduced. Consequently, the length of the arc discharge 7 is reduced, and thus the electrical input power to the arc discharge 7 at the time of current break is reduced.

[0063] In the case of gas circuit breakers that utilize the self-pressure-increase action by the arc heat, a reduction of the electrical input power to the arc discharge 7 is not desirable since this results in a reduction of the self-pressure-increase action. However, the embodiment utilizes no self-pressure-increase action by the arc heat, and thus the reduction of the electrical input power to the arc discharge 7 does not affect the current breaking performance at all.

[0064] Hence, even if the stationary arc electrodes 35a, 35b are thickened, only the advantage such as a contribution to the thermal durability improvement is obtainable. Note that the trigger electrode 34 wears while the arc discharge 7 is igniting, but such time period is only within the initial stage of the current breaking procedure until the arc discharge 7 is transferred to the stationary arc electrode 35b, and thus the wear is limited. Hence, the maintenance necessary for the trigger electrode 34 is reduced.

[0065] Meanwhile, in order to increase the pressure of the arc-extinguishing gas 1 without utilizing the self-pressure-increase action by the arc heat, a compression gas may be produced in a high-pressure reservoir tank beforehand by a compressor, a circuit open valve may be synchronously opened with the current breaking action, and the compression gas may be blown to the arc discharge 7. In order to achieve such structure, however, the number of accessory components, such as the reservoir tank, the compressor, and an electromagnetic valve, increases. This results in the increase in size of the device and costs, while at the same time, a reduction of the maintenance easiness.

[0066] According to the first embodiment, however, a quite simple structure is achieved in which the pressure inside the sealed container is a single pressure, e.g., the filling pressure of the arc-extinguishing gas 1, at any sites in the normal actuation, and the necessary compression gas is produced only in the current breaking procedure. Hence, according to the first embodiment, although a single-pressure scheme is applied, the necessary compression gas can be produced only in the current breaking procedure. This achieves a downsizing of the device, and a cost reduction, and also a reduction of the work load for the maintenance necessity.

(C) Reduction of the current breaking time

[0067] As explained above, according to conventional gas circuit breakers, when the pressure of the arc-extinguishing gas 1 in the puffer chamber 16 is increased to the necessary blowing pressure to break the current by utilizing the self-pressure-increase action by the arc heat, a time is necessary to some extent. Hence, according to conventional gas circuit breakers that utilize the self-pressure-increase action by the arc heat, the time for the current breaking to complete is tended to be extended.

[0068] In contrast, according to the embodiment, since no self-pressure-increase action by the arc heat is utilized, the pressure of the arc-extinguishing gas 1 blown to the arc discharge 7 and the flow rate thereof are always constant regardless of the current condition. In addition, the timing to start blowing to the arc discharge 7 is determined in accordance with the timing at which the trigger electrode 34 passes through the nozzle throat 37 or the stationary arc electrode 35b to release the closing component 45, thus is always constant regardless of the current condition. Hence, unlike conventional gas circuit breakers, the completion time for current breaking is not extended depending on the breaking current condition, meeting a demand to reduce the completion time for current break.

(D) Reduction of the drive and actuation energy

[0069] In general, the closer the drive stroke comes to the complete current breaking position, the higher the pressure of the compression gas in the pressure increase chamber 40 and the accumulating chamber 42 becomes, while at the

same time, the larger the compression repulsion force applied to the movable piston 38 becomes. In order to get over such force, it is necessary to provide a drive device that has enough drive force .

[0070] According to the embodiment, however, at the complete current breaking position, the sealing members 46 provided on the movable piston 38 block the communication hole 39, and thus the pressure increase chamber 40 is isolated from the accumulating chamber 42 in terms of pressure, and the pressure inside the pressure increase chamber 40 is released by the pressure relief 47. Hence, as long as there is a drive energy that is capable of pulling the movable component at least to the complete current break position, no force in the backward direction to the stroke subsequently acts on the movable piston 38. Therefore, a backward stroke movement does not happen. In addition, this hardly affects the current condition.

[0071] If it was not this embodiment with such effect, there will be a needs to ensure the drive energy that is excessive under other breaking current conditions than the break current condition in which the pressure of the heat exhaust gas increases. In addition, an additional mechanism to maintain the stroke position at the complete current breaking position is required, resulting in a cost increase and a reduction of the mechanical reliability. According to the embodiment, however, those disadvantages are avoidable, and a reduction of the drive and actuation energy is achieved.

[0072] Achievement of the reduction of the drive and actuation energy is particularly desirable when employing a spring actuation mechanism, etc., which decreases the drive force together with the current breaking action . In addition, according to the embodiment, since the plurality of supports 21 and links 31 is provided in the angular direction, an axial displacement is preventable, avoiding an excessive concentration of mechanical force to a single site, thereby enabling the stable action.

[0073] Still further, the trigger electrode 34 has a smaller diameter than those of the stationary arc electrodes 35a, 35b, and is lightweight in comparison with the movable arc electrode 4 and the drive rod 6 according to conventional technologies. Yet still further, since the insulation nozzle 81 is not included in the movable component in addition to the two stationary arc electrodes 35a, 35b, the weight of the movable component is remarkably reduced. According to the embodiment in which the movable component is further made lightweight, in view of an obtainment of the necessary electrode opening speed of the movable component to break the current, the drive and actuation force is remarkably reduced.

[0074] When, together with the weight reduction, reduction of the necessary blowing pressure itself to break the current is achieved, the necessary energy for the compression is also reduced. According to the embodiment, in comparison with conventional technologies, the gas temperature blown to the arc discharge 7 is quite low. Hence, the cooling efficiency for the arc discharge 7 is remarkably improved, and in comparison with a case in which the high-temperature blown gas 15a is blown, the arc discharge 7 can be extinguished even at a low pressure.

[0075] In addition, blowing the low-temperature gas 15b to the arc discharge 7 to be concentrated toward the center from the surrounding of the arc discharge 7 also results in a reduction of the necessary blowing pressure to break the current. In particular, as illustrated in FIGs. 1C, 1D, when the low-temperature blown gas 15b is blown to the arc discharge 7 to be concentrated toward the center around the surrounding of the arc discharge 7, the arc discharge diameter at the blown point by the gas is reduced, enabling a further efficient cooling for the arc discharge 7. However, the current can be broken by other schemes than this blowing scheme to the arc.

[0076] Still further, according to the embodiment, the flow channel area flowing in from the external side of the arc discharge 7 is designed to be larger than the total cross-sectional area of the internal diameter part of the nozzle throat 37 and that of the stationary arc electrode 35b which is the discharging area of the heat exhaust gas 14. Hence, the sufficient flow rate of the low-temperature blown gas 15b to cool the arc discharge 7 is ensured. In view of these points, by blowing the low-temperature compression gas to the arc discharge 7 from the surrounding thereof toward the center, the arc discharge 7 can be extinguished even at a further lower pressure.

[0077] Yet still further, until the trigger electrode 34 is sufficiently opened and disconnected from the stationary arc electrode 35a, and the arc-extinguishing gas 1 is blown to the arc discharge 7, the pressure increase chamber 40 and the accumulating chamber 42 are blocked by the closing component 45. That is, the closing component 45 restricts the flow-in of the heat exhaust gas 14 from the arc discharge 7 to the sealed space formed of the pressure increase chamber 40 and the accumulating chamber 42, and also restricts the flow-out of the arc-extinguishing gas 1 that is being subjected to pressure increase in such a sealed space. Hence, except the leakage of a quite small gap that is inevitable in terms of structure, the compression energy applied by the movable piston 38 is substantially completely converted to the pressure energy of the arc-extinguishing gas 1 in the sealed space (pressure increase chamber 40 and accumulating chamber 42).

[0078] This is quite advantageous in comparison with conventional gas circuit breakers (see FIG.7B) which starts the discharging of the pressure-increased gas during the compression of the arc-extinguishing gas 1. Hence, according to the embodiment, unlike conventional technologies which lose the compression energy given from the exterior by the puffer cylinder 9 and the stationary piston 11, all compression energy by the movable piston 38 is utilized to increase the pressure in the pressure increase chamber 40 and in the accumulating chamber 42 without a loss. This is also advantageous in the reduction of the drive and actuation energy.

[0079] In addition, according to the embodiment, the heat exhaust gas 14 produced from the arc discharge 7 flows in the direction apart from the arc discharge 7 simultaneously with the production of the arc discharge 7 without a delay, and is quickly discharged to the internal space of the sealed container. The low-temperature blown gas 15b to the arc discharge 7 is caused to flow by a pressure difference between the pressure of the accumulating chamber 42 at the upstream side and the pressure around the stationary arc electrode 35a at the downstream side. Hence, as long as the pressure at the downstream side is high, no matter how much the pressure at the accumulating chamber 42 is increased, a sufficient blowing force cannot be obtained.

[0080] Hence, according to the embodiment, simultaneously with the production of the arc discharge 7, the heat exhaust gas 14 is discharged to the sealed container quickly through the wide discharge channel. Hence, the pressure at the downstream side, such as the pressure around the stationary arc electrode 35a is always maintained at the substantially equal level to the filling pressure in the sealed container. In view of this point, also, according to the embodiment, the necessary blowing pressure to break the current is reduced in comparison with conventional gas circuit breakers, resulting in a reduction of the drive and actuation energy.

[0081] In addition, the pressure of the heat exhaust gas 14 produced from the arc discharge 7 acts on the left side face of the movable piston 38 in FIGs. 1A-1E. That is, unlike conventional gas circuit breakers, according to this embodiment, a mechanical compression is performed at the right side face of the piston, namely the opposite side surface to the surface on which the pressure of the heat exhaust gas 14 acts. Hence, the pressure of the heat exhaust gas 14 may become assist force for the compression by the movable piston 38, but hardly acts as repulsion force against the drive and actuation force of at least the movable piston 38 at all. In view of this point, also, according to the embodiment, a reduction of the drive and actuation energy is achieved.

[0082] Furthermore, for example, if the exhaust opening 33 for the heat exhaust gas 14 from the heat exhaust gas reserving chamber 44 is narrowed, the pressure of the heat exhaust gas reserving chamber 44 relatively increases. When the size of the exhaust opening 33 is adjusted as appropriate so as not to disturb the discharging of the heat exhaust gas 14 from the arc discharge 7, the pressure of the heat exhaust gas 14 in the heat exhaust gas reserving chamber 44 may as well be utilized as the assist force for the drive and actuation.

(E) A gas flow stabilization

[0083] As repeatedly explained above, according to the embodiment, the self-pressure-increase action by the arc heat is not utilized at all for increasing the blowing pressure of the arc-extinguishing gas 1. Hence, regardless of the break current condition, the blowing gas pressure and the gas flow rate that are always stable and equal are obtainable. Hence, an instability of the performance in accordance with the magnitude of the current to be broken does not occur at all.

[0084] Meanwhile, it is known how the arc-extinguishing gas 1 in the insulation nozzle flows quite largely affects the current breaking performance. Since the insulation nozzle 8 of conventional gas circuit breakers is assembled in the movable component, such nozzle is driven in the current breaking action, and thus the flow of the arc-extinguishing gas 1 in the insulation nozzle 8 largely varies depending on the stroke position per an action or the speed of electrode opening, etc. Accordingly, it is difficult to always obtain an ideal flow channel shape for the arc-extinguishing gas 1 across the entire current condition.

[0085] In contrast, according to the embodiment, the insulation nozzle 81, and the arc electrodes 35a, 35b are all immobilized. Hence, the relative positional relationship among those components does not change at all, and no self-pressure-increase action by the arc heat is utilized at all. Hence, the pressure of the pressure-increased gas to be blown to the arc discharge 7 and the flow rate thereof are always constant regardless of the current condition. This enables an optimization of the flow channel in the insulation nozzle 81. As explained above, according to the embodiment, by a simple structure, a reduction of the temperature of the blown gas, an improvement of the durability and a reduction of the maintenance frequency, a reduction of the current breaking time, a reduction of the drive and actuation energy, and a stabilization of the gas flow are all achievable.

(2) Second Embodiment

(Structure)

[0086] The second embodiment employs the same basic structure as that of the first embodiment. Features in structure according to the second embodiment are that, as illustrated in FIG.4, the insulation nozzle 81 is divided into two portions, and a sub insulation nozzle 50 is provided at the stationary-arc-electrode-35b side. The low-temperature blown gas 15b is delivered to the arc discharge 7 from the accumulating chamber 42 via a gap between the sub insulation nozzle 50 and the insulation nozzle 81. In this case, the sub insulation nozzle 50 is formed to blow the low-temperature gas 15b to the middle site of the arc discharge 7.

(Action and Effect)

[0087] According to the second embodiment, the sub insulation nozzle 50 is provided at the stationary-arc-electrode-35b side, and the low-temperature blown gas 15b is blown to the middle site of the arc discharge 7. Hence, an amount of heat of the heat exhaust gas 14 flowing into the left side of the arc discharge 7 is balanced with the amount of heat of the heat exhaust gas 14 flowing into the right side of the arc discharge 7.

[0088] Therefore, the low-temperature blown gas 15b will not be blown around the stationary arc electrode 35b, namely will not be blown unbalanced, such as to either one side of the arc electrode 7. Hence, for example, a concern that the damage level of the component due to the flow of the heat exhaust gas 14, and the reduction level of the electrical insulation performance between the high-voltage site and the ground potential that are the sealed container being remarkably deteriorated at only either one side of the arc discharge 7, is unnecessary.

[0089] Since the low-temperature blown gas 15b is not unevenly blown to either one side of the arc discharge 7, a concern such as the flow of the heat exhaust gas 14 at either one side being unbalanced is unnecessary. That is, a sufficient flow rate of the heat exhaust gas 14 is always ensured. Hence, when the pressure in the heat exhaust gas reserving chamber 44 is increased and utilized to assist the drive force for the movable piston 38, the above effect is fully achievable.

(3) Third Embodiment

(Structure)

[0090] A third embodiment employs the same basic structure as that of the first or second embodiment, but relates to a drive device for the movable component which is not illustrated in FIGs. 1A-1E, 2, 3, and 4. A drive device which has an output attenuating characteristic and which is illustrated in FIG. 6 is applied in this embodiment. According to the drive device, the drive force decreases during the current breaking procedure.

[0091] In FIGs. 5 and 6, a compression repulsion force (a) namely the force received by the movable piston 38 from the pressure of the pressure increase chamber 40 is indicated by a continuous line, a drive force (e) by the drive device is indicated by a dotted line, and a force (actual acceleration force (e-a)) that accelerates the movable component is indicated by a dashed-dotted line. The horizontal axis represents a drive stroke, the complete loading position is at 0 pu, and the complete electrode opening position is at 1.0 pu. In the case when influences due to friction, etc., are ignorable, the actual acceleration force is expressed as "drive force (e) - compression repulsion force (a)". The actual acceleration force has a positive value meaning an acceleration force, and a negative value meaning a deceleration force.

[0092] In this case, as explained in the first embodiment, the gas circuit breaker according to the embodiment achieves the pressure increase of the blown gas mainly through the thermal insulation compression by the movable piston 38. Hence, as illustrated in FIGs. 5 and 6, the compression repulsion force ((a), continuous line) has a curve with a monotonic increase characteristic that is known as a thermal insulation compression characteristic. In addition, since the gas circuit breaker according to the embodiment utilizes no thermal energy from the arc to increase the pressure of the blown gas, the compression repulsion force (continuous line) has an always constant curve regardless of the magnitude of the current to be broken, the phase of an AC current, etc.

[0093] FIG. 5 illustrates a case in which the drive force ((e), dotted line) by the drive device has a flat characteristic relative to the drive stroke. On the other hand, FIG. 6 illustrates a case in which the drive force ((e), dotted line) by the drive device has an attenuating characteristic relative to the drive stroke. In FIG. 5, as the most drastic example, the drive force is constant at 0.5 pu across the entire stroke position. On the other hand, in FIG. 6, as an example case, the drive force linearly attenuates from 0.8 pu to 0.2 pu.

[0094] Note that the drive energy accumulated by the drive device to break the current is given as an area obtained by integrating the drive force ((e), dotted line) by the stroke. In the case of the drive force characteristic in FIG. 5, the drive energy is obtainable from the following formula (1).

$$0.5 \text{ pu} \times \text{entire stroke } 1 \text{ pu} = 0.5 \quad (1)$$

[0095] On the other hand, in the case of the drive force characteristic in FIG. 6, the drive energy is given by the area of a trapezoid defined by the vertical axis line at 0 pu, and the dotted line of the drive force (e), and is obtainable from the following formula (2).

$$(0.8 \text{ pu} + 0.2 \text{ pu}) \div 2 \times \text{entire stroke } 1 \text{ pu} = 0.5 \quad (2)$$

5 **[0096]** That is, although FIGS. 5, 6 have different stroke characteristics for the drive force, these have the same drive energy.

(Action and Effect)

10 **[0097]** In general, the size of a drive device and the costs thereof have a tendency of substantially monotonic increase relative to the drive energy. That is, although FIGS. 5, 6 have difference characteristics for the drive force, these have the same drive energy. Hence, there would be no large difference in size and costs of the drive device between both cases.

[0098] On the other hand, although the drive energy is equal, it is clear that the drive device in FIG. 6, which outputs a large drive force at the first half stage of the stroke, and which has the drive force attenuating at the latter half stage of the stroke, has a larger actual acceleration force (e-a) than that of FIG. 5. Since the compression repulsion force (a) has the same characteristic in both FIGs. 5 and 6, and the drive energy is equal too, the speed at the complete electrode opening position (stroke 1 pu) is the same speed, but is quite different during the stroke procedure in FIGS. 5 and 6. That is, the case in FIG. 6 which has the larger acceleration force at the first half stage of the electrode opening has a faster top speed of the movable component.

20 **[0099]** This shows that, when the drive and actuation energy is equal, the drive device that has the output attenuating type drive characteristic illustrated in FIG. 6 is capable of speeding up the drive speed of the movable component faster in comparison with the drive device that has the drive characteristic in FIG. 5. That is, for the gas circuit breaker, the gap between the electrodes is opened faster, resulting in a remarkable advantageous for a quick recovery of the electric insulation performance between the electrodes.

25 **[0100]** In addition, the faster the drive speed of the movable component becomes, the faster the arc discharge 7 is transferred from the trigger electrode 34 to the stationary arc electrode 35b, and the shorter the time until the low-temperature blown gas 15b is powerfully blown to the arc discharge 7 from the accumulating chamber 42 becomes. Hence, an improvement of the durability, and a reduction of the necessary time until the current breaking completes can be achieved.

30 **[0101]** The reason why the action and effect explained above are obtained is because the gas circuit breaker of the embodiment achieves the pressure increase of the blown gas mainly through the adiabatic compression by the movable piston 38, and thus the compression repulsion force has a characteristic which is quite small at the initial stage, and which keenly increases toward the latter half stage. In addition, the characteristic of the compression repulsion force that has an always constant curve regardless of, for example, the magnitude of the current to be broken and the phase of the AC current is an essential condition to obtain the above action and effect. In any cases, this is a feature that cannot be achieved by the structure of conventional gas circuit breakers. Conventional gas circuit breakers are not capable of obtaining a monotonic increase curve since the compression repulsion force applied to the stationary piston 11 is largely affected by the heat generated by an arc, and have a condition that remarkably varies depending on the break current condition.

35 **[0102]** A specific scheme of obtaining the drive output that has the attenuating characteristic in FIG. 6 from the flat characteristic in FIG. 5 will be explained below. This is easily achieved when a drive energy source that is a compressed spring is applied. The output characteristic of the spring mechanism is given by the following formula 3 in principle, and becomes a monotonically decreasing straight line relative to stroke x (pu) illustrated in FIG. 6.

$$45 \quad F = k(L + 1 - x) \quad (3)$$

where F is a drive output, k is a spring constant, x is a stroke (pu), and L is a compression length (pu) of the spring at the complete electrode opening position (stroke x = 1pu).

50 **[0103]** In particular, by setting the spring to become close to a free length at the complete electrode opening position ($L \cong 0$ pu), the value of the spring constant k becomes larger to obtain the same drive energy, and thus a characteristic of largely attenuating the drive force relative to the stroke together with a release of the spring is obtained. Alternatively, when a drive device like a hydraulic actuation mechanism that has a relatively flat output characteristic relative to the stroke is applied, by coupling an appropriate linkage mechanism, the output characteristic may be changed to the attenuating type without making a change in drive and actuation energy.

55 **[0104]** Various schemes of setting the output characteristic to the attenuating type other than the above scheme are also adoptive, but what is important is that, according to the gas circuit breaker of the embodiment, by combining the

mechanism that attenuates the drive force relative to the stroke, the speed of opening and disconnecting the electrode can be effectively increased even at same drive and actuation energy, resulting in obtaining unique advantageous effects such as a quick recovery of the insulation performance of the circuit breaker, a reduction of the necessary time until the current break completes, an improvement of the durability, etc.

[0105] Still further, by employing the structure explained in the first embodiment in which the high gas pressure in the pressure increase chamber 40 is isolated from the pressure in the accumulating chamber 42, and the pressure in the pressure increase chamber 40 is released by the pressure relief 47, even if the drive force largely decreases at the latter half stage of the electrode opening action, a disadvantage such as a backward movement of the movable component does not happen. Note that an example rough standard for the drive force characteristic that decreases the output is that the drive force at the complete current breaking position (stroke 1 pu) is, for example, desirably equal to or smaller than 80 % relative to the drive force at the closing position (stroke 0 pu). A setting of the output reduction rate to be equal to or smaller than 80 % at the complete electrode opening position enables a substantial achievement of the above action and effect.

(4) Other Embodiments

[0106] The above embodiments are merely presented as examples in the specification, and are not intended to limit the scope of the present disclosure. That is, the present disclosure can be carried out in other various forms, and various omissions, replacements, and modifications can be made thereto without departing from the scope of the present disclosure. Such embodiments and modified forms thereof are within the scope of the present disclosure, and also within the scope and the spirit of the invention as recited in the appended claims, and the equivalent range thereto. For example, in the second embodiment, the explanation has been given of the example structure in which the sub insulation nozzle 50 is provided at the stationary-arc-electrode-35b side, and the insulation nozzle 81 is divided into two portions, but the number of divided portions is not limited to two, and may be equal to or greater than three.

REFERENCE SIGNS LIST

[0107]

1	Arc-extinguishing gas
2	Opposing arc electrode
3	Opposing current-flowing electrode
4	Movable arc electrode
5	Movable current-flowing electrode
6, 36	Drive rod
7	Arc discharge
8, 81	Insulation nozzle
9	Puffer cylinder
11	Stationary piston
12	Intake port
13	Intake valve
14	Heat exhaust gas
15a	High-temperature blown gas
15b	Low-temperature blown gas
16	Puffer chamber
17	Slide contact
18a, 18b	Terminal
19, 31	Link
20, 32	Rib
21	Support
22	Flange
33	Discharge opening
34	Trigger electrode
35a, 35b	Stationary arc electrode
36	Drive rod
37	Nozzle throat
38	Movable piston

39	Communication hole
40	Pressure increase chamber
41	Pressure-increase-chamber cylinder
42	Accumulating chamber
5 43	Accumulating-chamber cylinder
44	Heat exhaust gas reserving chamber
45	Closing component
46	Sealing member
47	Pressure relief
10 48	Discharge compression gas
49	Heat dissipation hole
50	Sub insulation nozzle

Claims

1. A gas circuit breaker comprising:

a pair of arc electrode disposed facing each other in a sealed container filled with an arc-extinguishing gas, the arc electrodes being capable of electrically flowing a current, an arc discharge being produced between both the electrodes at a time of current breaking action;

a pressure increaser increasing a pressure of the arc-extinguishing gas to produce a pressure-increased gas in order to blow the arc-extinguishing gas to the arc discharge;

an accumulating space reserving the pressure-increased gas;

an insulation nozzle delivering the pressure-increased gas toward the arc discharge from the accumulating space;

a switch causing the accumulating space to be in a closed state or a released state; and

a trigger electrode disposed between the arc electrodes so as to be freely movable therebetween, and producing the arc discharge together with a movement,

wherein the switch comprises a gap between the arc electrode and the trigger electrode, a gap between the insulation nozzle and the trigger electrode, or both of the gaps.

2. The gas circuit breaker according to claim 1, wherein:

the switch is in the closed state at a first half stage of the current breaking action, restricts a flow-in of a heat exhaust gas produced by heat of the arc discharge to the accumulating space, and restricts a flow-out of the arc-extinguishing gas being subjected to the pressure increase in the accumulating space; and

the switch is in a released state at a latter half stage of the current breaking action, and delivers the pressure-increased gas in the accumulating space to the arc discharge.

3. The gas circuit breaker according to claim 1 or 2, wherein the pressure-increased gas is blown to the arc discharge from a surrounding of the arc discharge to a center thereof.

4. The gas circuit breaker according to any one of claims 1-3, wherein:

the pair of arc electrodes is fixed in the sealed container;

the trigger electrode having a smaller diameter than a diameter of the arc electrode is disposed inwardly relative to the pair of arc electrodes so as to be freely movable therebetween;

the trigger electrode achieves a current-flowing state by electrically contacting to the arc electrode, the arc discharge is produced between the trigger electrode and one of the arc electrodes at the time of current breaking action, and the produced arc discharge is eventually transferred to the other arc electrode from the trigger electrode.

5. The gas circuit breaker according to claim 3 or 4, wherein:

the pressure increaser comprises a cylinder and a piston, at least either one of the cylinder and the piston moves to compress the arc-extinguishing gas in the cylinder, thereby producing the pressure-increased gas; and

a pressure of a heat exhaust gas produced from the arc discharge is prevented from acting as a compression

repulsion force to the arc-extinguishing gas by the piston or the cylinder.

5 6. The gas circuit breaker according to claim 5, further comprising a heat exhaust gas reserving space to temporarily reserve the heat exhaust gas produced from the arc discharge,
wherein a pressure in the heat exhaust gas reserving space is caused to act as assist force to the compression of the arc-extinguishing gas by the piston or the cylinder.

10 7. The gas circuit breaker according to claim 5 or 6, wherein at the latter half stage of the current breaking action, a compression space for the arc-extinguishing gas by the piston and the cylinder is isolated from the accumulating space reserving the arc-extinguishing gas in terms of pressure.

8. The gas circuit breaker according to claim 7, wherein at the latter half stage of the current breaking action, a pressure in the compression space is released.

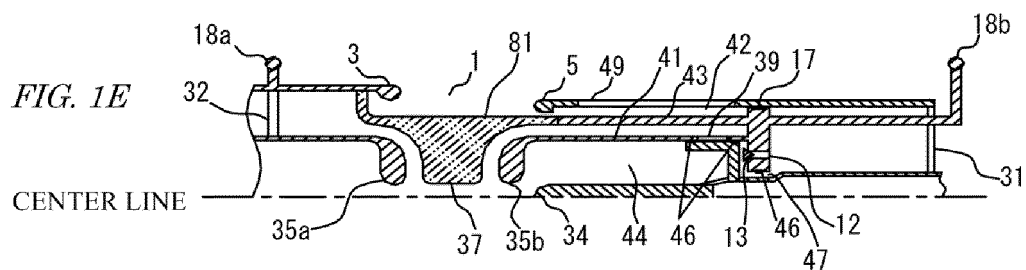
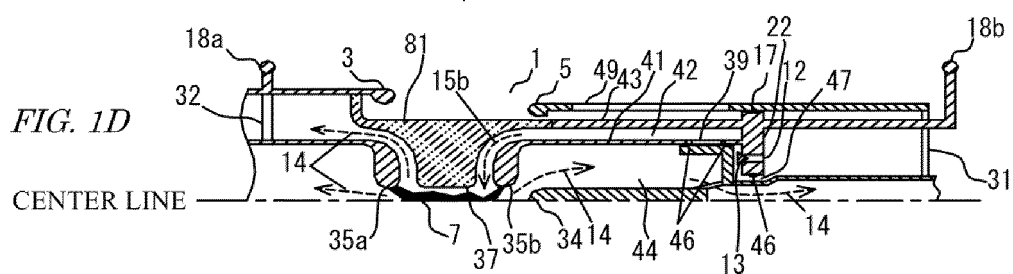
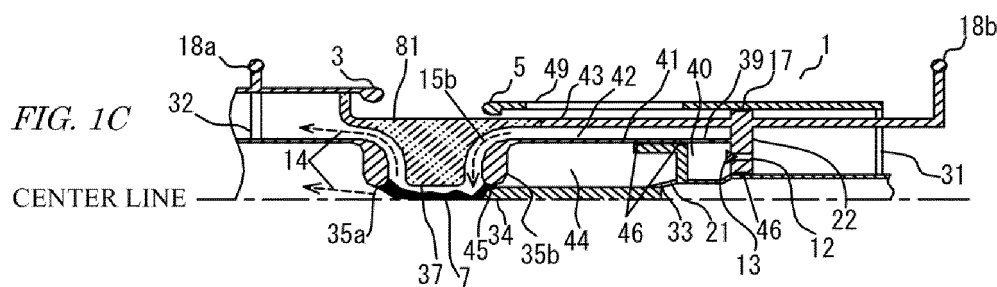
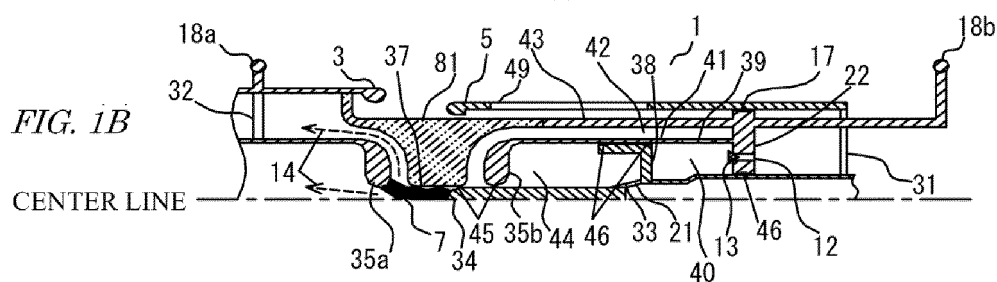
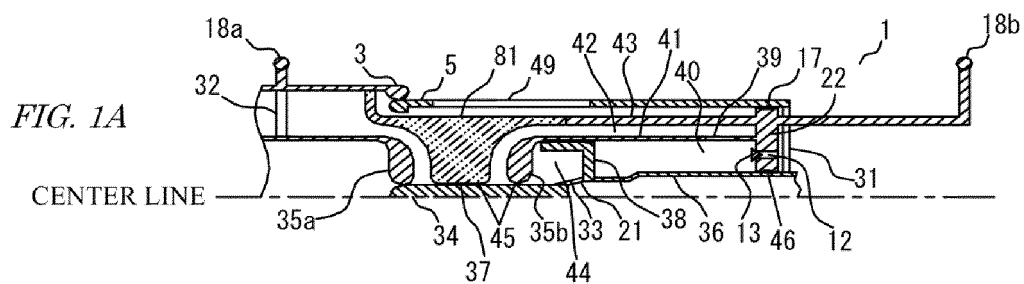
15 9. The gas circuit breaker according to claim 8, further comprising a drive device to mechanically compress the arc-extinguishing gas,
wherein the drive device is configured to reduce drive force in accordance with a drive stroke.

20 10. The gas circuit breaker according to any one of claims 1-9, wherein a heat exhaust gas produced from the arc discharge flows in a direction apart from the arc discharge simultaneously with the production of the arc discharge without a delay, and is quickly discharged to an internal space of the sealed container.

11. The gas circuit breaker according to any one of claims 1-10, wherein:

25 the insulation nozzle is divided into at least two portions, the pressure increased gas is delivered from the accumulating space to the arc discharge through a gap between the divided portions; and
the pressure-increased gas is blown to a middle site of the arc discharge.

30 12. The gas circuit breaker according to any one of claims 1-11, wherein the insulation nozzle is fixed in the sealed container.



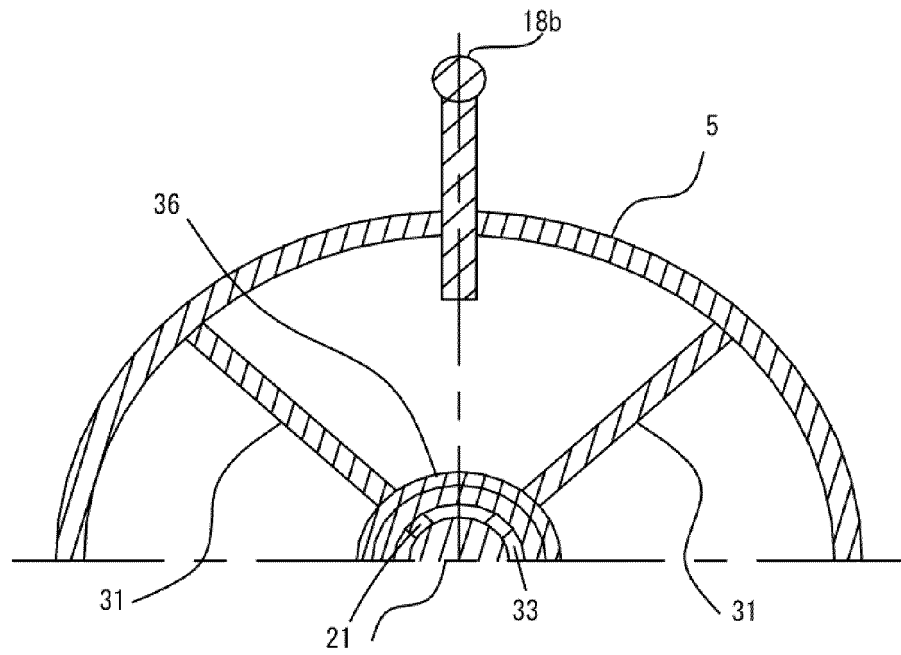


FIG. 2

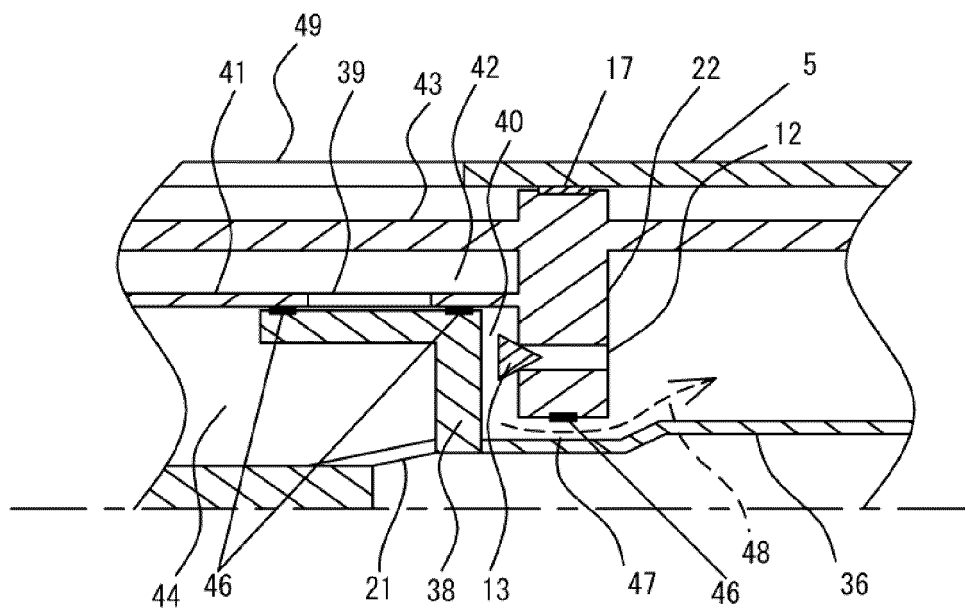


FIG. 3

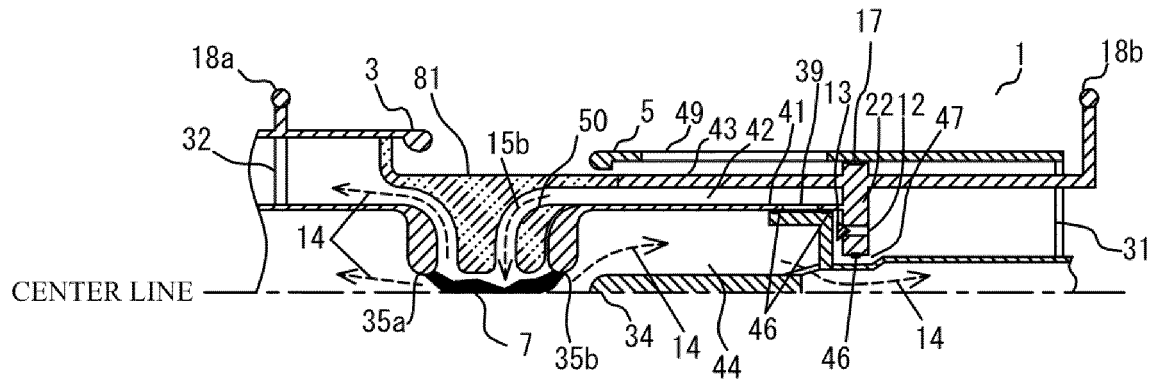


FIG. 4

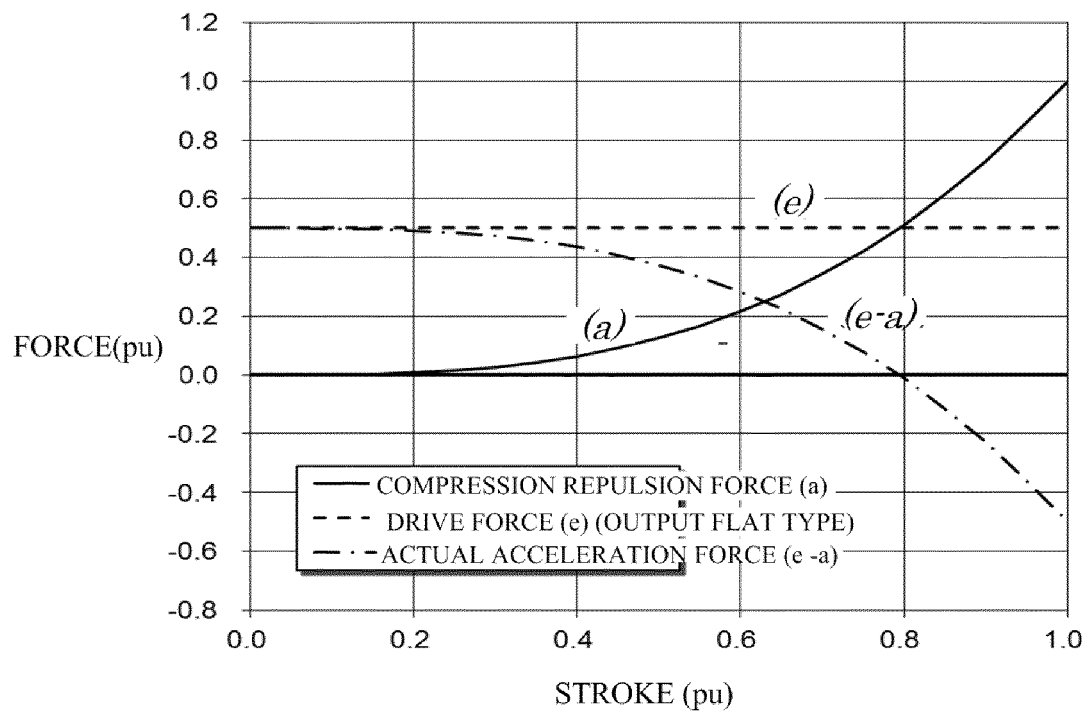


FIG. 5

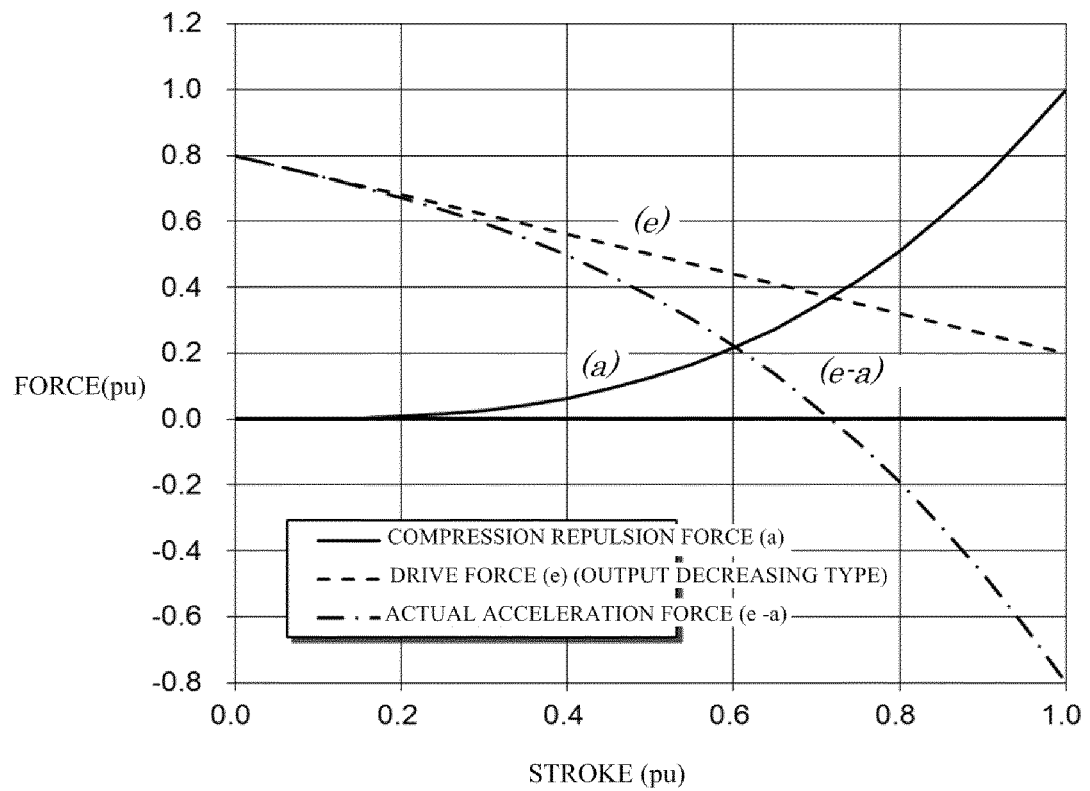
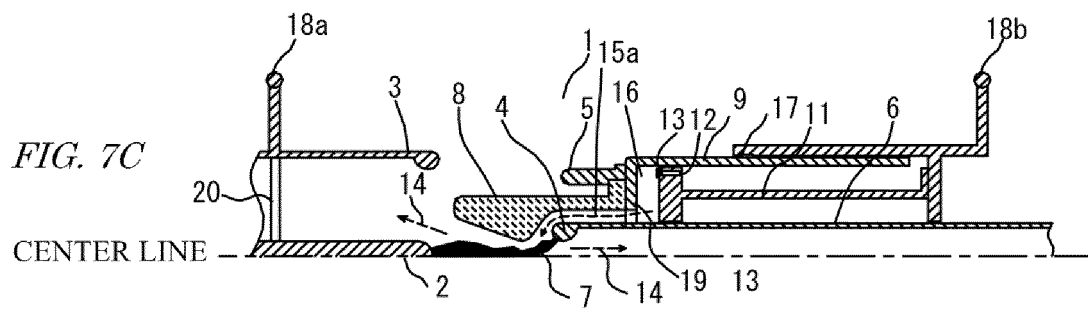
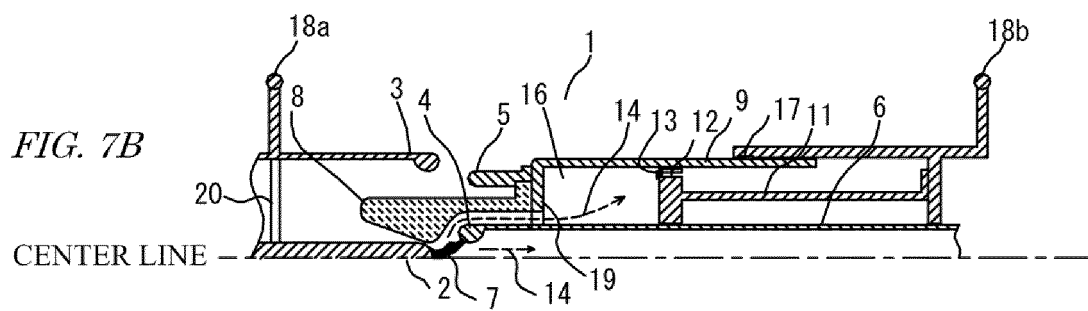
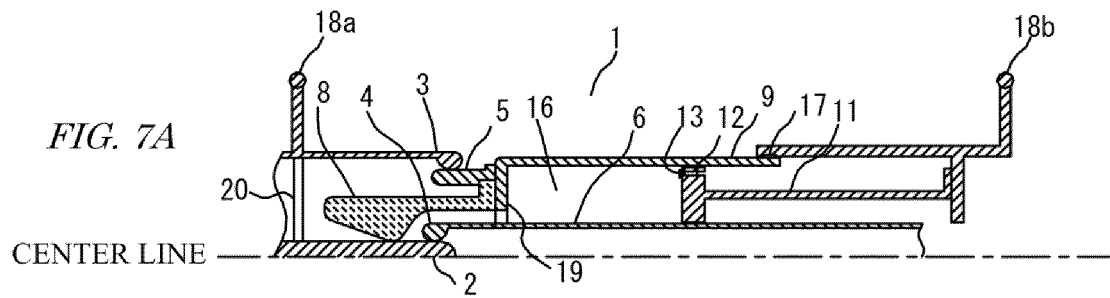


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/054620

A. CLASSIFICATION OF SUBJECT MATTER

H01H33/915 (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)

H01H33/915, H01H33/91

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 1996-2015
 Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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.
Y	JP 11-329191 A (ABB Research Ltd.), 30 November 1999 (30.11.1999), paragraphs [0008] to [0026]; fig. 1, 2 & US 6163001 A & EP 0951039 A1 & DE 19816505 A1 & CN 1232280 A	1-12
Y	JP 2002-203463 A (ABB Hochspannungstechnik AG.), 19 July 2002 (19.07.2002), paragraphs [0002], [0010], [0011]; fig. 1 & US 2002/060203 A1 & EP 1207544 A1 & CN 1354488 A & RU 2273071 C2	1-12
Y	US 4486632 A (BBC Brown, Boveri & Co., Ltd.), 04 December 1984 (04.12.1984), column 2, line 67 to column 3, line 7; fig. 1 & EP 0067460 A1	6

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

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"&" document member of the same patent family

Date of the actual completion of the international search
08 May 2015 (08.05.15)Date of mailing of the international search report
19 May 2015 (19.05.15)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/054620

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-348580 A (Fuji Electric Co., Ltd.), 15 December 2000 (15.12.2000), entire text; all drawings & KR 10-2000-0053383 A & CN 1259753 A	8, 9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H07109744 A [0012]