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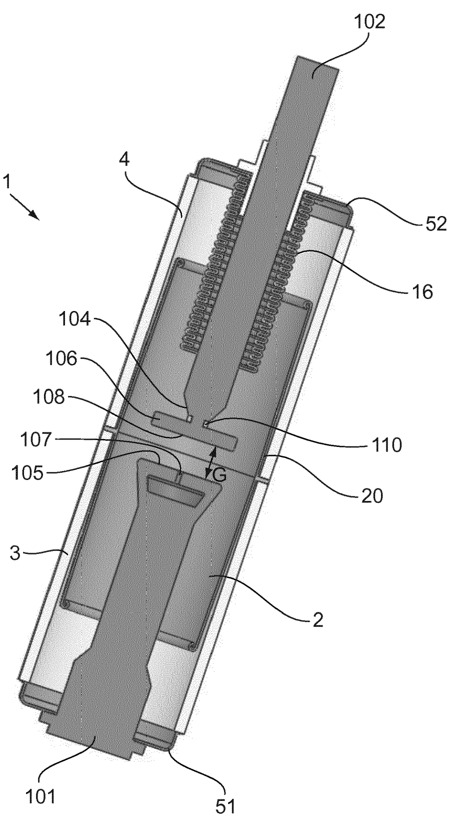
(54) **VACUUM SWITCH**

(57) The object of the present invention is a vacuum switch (1) comprising an insulating case (3, 4) made of a suitable insulating material, two conducting caps (51, 52) each securely fixed at an opening of the insulating case (3, 4) to form a sealed vacuum chamber (2) and a first contact (101) and a second contact (102) inside the sealed vacuum chamber (2) and movable with respect to one another between a first open positon in which the first and second contacts (101, 102) are not in contact and a closed position in which the first and second contacts (101, 102) are in contact. The vacuum switch and the first and second contacts (101, 102) are designed so as to remain in the closed position in case of a high short circuit current passing through the said contacts (101, 102) when they are in the closed position. The vacuum switch according to the invention is in particular designed to be used as an air-insulated grounding switch or as a disconnector in an electrical circuit for railway applications.

Fig.2



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Description

[0001] The present invention relates to a vacuum switch designed for use as a grounding (earthing) switch or as a disconnector, in particular for railway applications.

[0002] Electrical grounding (or earthing) is necessary for safety reasons in case of inspection, maintenance, repair, or replacement of some electrical equipment such as capacitor banks, circuit breakers, circuit switchers, etc. Grounding switches or devices can be available as stand-alone devices or combined with other electrical devices such as disconnectors, circuit breakers, and other switching devices. Grounding devices are usually operated through manual handling by an operator, via a manual gear operator, or a hook stick, or via an electromechanical actuator (coil, electric motor...).

[0003] For railway applications, the usual and simplest solution for electrical grounding is an air-insulated grounding switch comprising two moving arms. The arms are designed to move between an open position and a closed position in which they are slotted in corresponding grounding fingers connected to the ground. Usually, such air-insulated grounding switches are designed to fulfil the following requirements of electrical grounding:

i. Provide enough clearing distance between the arm(s) and the finger(s) in open state;
ii. Provide closing/opening on off-load, with no need of fast opening/closing operations;
iii. Withstand any high short circuit (SC) current in closed position;
iv. Maintain the switch in closed position in case of short circuit current occurrences.

[0004] There are two main drawbacks of this type of air-insulted grounding switch for railway applications: due to the somewhat large clearing distance needed between the arms and the grounding fingers (at least 200 mm for 25kV AC rolling stock), the grounding switch takes a lot of space. This is especially challenging for medium voltage applications. Then, the positioning of the switch on the roof of the rolling stock in open air implies that said switch is subjected to harsh environmental conditions (snow, ice, dust, soot, birds...). This may prevent the arms from lodging securely inside their respective grounding fingers while closing, which can compromise severely the safe operation and the performance of the grounding switch.

[0005] Another option is to use a gas such as SF_6 for the insulation of the grounding switch in an enclosed and sealed housing. However, such gas-insulated grounding switches are costly, complex and delicate devices. Gas-pressure should be monitored at all time and as such they are not entirely suitable to be used on the roof of rolling stock where they would be subjected to high mechanical stress and harsh environmental conditions. Moreover, SF_6 is a greenhouse gas involved in global warming and therefore its use should be avoided.

[0006] Solid insulated switchgear which are equipped with solid-insulated grounding switches are a more environment friendly option. Such a switchgear generally use epoxy resin as insulation material instead of SF_6. They require low-maintenance and are overall safer as they eliminate any risk of gas leak compared to the gas insulated switchgear. However, such solid insulated switchgear are still somewhat bulky, very heavy and cumbersome.

[0007] Another type of switch frequently used in railway application is the disconnector (isolating switch). A disconnector is a mechanical switching device which provides in the open position of its contacts an isolating distance in accordance with specified requirements. A disconnector is an off-load device which can be interlocked with other switching devices like circuit breaker and grounding switch. It is usually capable of opening and closing a circuit when either no or negligible current is broken or made or when no or insignificant voltage difference across the terminals of each poles of the disconnectors occurs. It is also capable of carrying current under normal circuit conditions and carrying current for a specified time under abnormal conditions as those of short circuit. Hence, the usual requirements for a disconnector are the same as requirements i. to iv. listed above for a grounding switch together with:

v. Withstand the permanent load current in the closed position of the contact
vi. Maintain the contacts in their open position during maintenance on the circuit.

[0008] With quite similar requirements between a grounding switch and a disconnector, the inconvenient mentioned above are still valid for a disconnector.

[0009] The aim of the present invention is therefore to provide a switch which can be used as a grounding switch or as a disconnector and which avoids all the drawbacks mentioned above. The invention intends to provide a solution for electrical grounding or disconnecting that is reliable, compact, cheap, suitable for railway applications, for use in open air or in enclosed space and for use as a standalone device or as a part of the switchgear or any electrical protecting system of a circuit.

[0010] The object of the present invention is a vacuum switch according to claim 1 its use for railway applications according to claim 14 and an electrical circuit comprising said vacuum switch according to claim 15.

[0011] Other advantages and features of the invention will become more clearly apparent from the following description of particular embodiments of the invention given as non-restrictive examples only and represented in the accompanying drawings.

Figure 1 illustrates a vacuum switch according to the invention.

Figure 2 is a cross-section of a vacuum switch according to a first embodiment of the invention in which the contacts are in open position.

Figures 3a and 3b illustrate the contacts of the vacuum switch according to a first variant of the first embodiment in open, respectively closed position. Figure 3c illustrates the current flow and induced attracting forces between the contacts in their closed position of figure 3b.

Figures 4a and 4b illustrate the contacts of the vacuum switch according to a second variant of the first embodiment in open, respectively closed position. Figure 4c illustrates the current flow and induced attracting forces between the contacts in their closed position of figure 4b.

Figure 5 illustrates the contacts of the vacuum switch according to a third variant of the first embodiment of the invention in their closed position.

Figure 6 is a cross-section of a vacuum switch according to a second embodiment of the invention in which the contacts are in open position.

Figures 7a and 7b illustrate the contacts of the vacuum switch according to the second embodiment in closed position. Figure 7b illustrates in particular the current flow and induced attracting forces between the contacts in their closed position.

Figure 8 is a cross-section of a vacuum switch according to a third embodiment of the invention in which the contacts are in open position.

Figures 9a and 9b illustrate the contacts of the vacuum switch according to a first variant of the third embodiment in open, respectively closed position. Figure 9c illustrates the current flow and induced attracting forces between the contacts in their closed position of figure 9b.

Figures 10a and 10b illustrate the contacts of the vacuum switch according to a second variant of the third embodiment in open, respectively closed position. Figure 10c illustrates the current flow and induced attracting forces between the contacts in their closed position of figure 10b.

Figure 11 illustrates the contacts of the vacuum switch according to a variant of the third embodiment of the invention in their open position.

Figure 12 illustrates the use of a vacuum switch according to the invention as a grounding switch in an electrical circuit.

Figure 13 illustrates a variant of the vacuum switch according to the invention.

[0012] The object of the invention is a vacuum switch 1 designed to perform electrical grounding or disconnecting in an electric circuit. The vacuum switch 1 according to the invention is preferably arranged to operate at high or medium voltage. Preferably, the vacuum switch 1 according to the invention is designed for railway applications.

[0013] The structure of the vacuum switch 1 according to the invention is generally similar to the structure of a known vacuum switch designed to act as a current circuit breaker in an electrical circuit.

[0014] The vacuum switch 1 generally comprises a sealed chamber 2 in which a controlled low pressure of air or another dielectric fluid preferably prevails, i.e. a vacuum. The chamber 2 is defined by an insulating case which is made of a suitable insulating material such as ceramic, glass-ceramic or glass for example. In the illustrated embodiments of the invention, the insulating case is tubular and preferably formed by two insulating cylinders 3, 4.

[0015] A conducting cap 51, 52 closes each open end of the sealed chamber 2. Preferably, the caps 51, 52 are made of metal. Any known technique can be used to effectively seal the caps 51,52 to the insulating case. For example, with a ceramic insulating case, the caps 51, 52 can be fixed on their respective cylinders 3, 4 by metallisation followed by brazing.

[0016] The sealed chamber 2 bounded by the insulating case 3, 4 and the conducting caps 51, 52 encloses a pair of acting contacts 101, 102 that are movable with respect to one another inside the sealed chamber 2. The contacts 101, 102 are movable with respect to one another between a first open position in which they are not in contact with each other and current cannot flow from one to the other and a second closed position in which they are in contact with each other and current can flow from one to the other.

[0017] Preferably, as illustrated, a first contact 101, called fixed contact, is stationary and securely attached to one of the caps 51. The second contact 102, called movable contact, is mounted inside the chamber 2 so as to be able to move through the other cap 52 between the closed and open position of the contacts. To enable the movable contact 102 to move and to maintain the controlled vacuum inside the sealed chamber 2, a sealing metallic bellows 16 is fitted between the movable contact 102 and the corresponding cap 52, thereby ensuring proper sealing of the chamber 2. A metallic bellows shield can be fitted around the sealing bellows 16, at the level of the end of the bellows 16 coupled to the movable contact 102. However, as will become clearly apparent below, this bellows shield is not essential to the vacuum switch according to the invention when used as a grounding switch or a disconnector.

[0018] The movable contact 102 moves between the open position in which the said movable contact 102 is not in contact with the fixed contact 101 (figures 2, 3a, 4a, 6, 8, 9a, 10a, 11 and 13) and the closed position in which the moving and fixed contact 102, 101 are in contact (figures 3b, 3c, 4b, 4c, 5, 7a, 7b, 9b, 9c, 10b and 10c).

[0019] The tightly sealed chamber 2 preferably further comprises a main shield 20 positioned at the contact area of the movable and fixed contacts 101, 102 around said contacts. In a traditional vacuum switch used as a circuit breaker, this main shield 20 is designed mainly to protect the insulating case 3, 4 against metallic vapour or any projections that might occur during arcing when the contacts are opened for load or short circuit current breaking.

Because no arcing activity is expected during grounding or disconnecting operation, the main shield 20 of the vacuum switch 1 according to the invention does not need to protect the insulating case 3, 4 against vapour or projection and thus can be removed (the same goes for the bellows shield). However, the shield 20 can be used and designed to shape the electric field and electric potential lines distribution when the vacuum switch 1 is in its open position. In this case, there are less requirements for the design of the main shield 20 of the vacuum switch 1 according to the invention than for a traditional shield of a known vacuum switch used for current breaking. For example, such low cost material as steel can be used for the main shield 20.

[0020] When the vacuum switch 1 according to the invention is used in an electrical circuit, the movable contact 102 is connected to an actuating mechanism M (pictured in figure 12) designed to displace said movable contact 102 between the open position and the closed position.

[0021] In railway applications, the actuating mechanism M is preferably actuated manually by the operator via a manual gear operator or hook stick or an electromechanical actuator such as a coil or an electric motor or any other appropriate mechanism.

[0022] When used as a grounding switch, the vacuum switch 1 according to the invention is connected at one contact to the electrical circuit while the other contact is connected to the ground. Preferably, as illustrated in figure 12, the fixed contact 101 of the vacuum switch 1 is connected to the electrical circuit while the movable contact 102 is connected to the ground. Hence, in this case, electrical grounding occurs when the fixed and movable contacts 101, 102 of the vacuum switch 1 are in closed position while there is no electrical grounding when the fixed and movable contacts 101, 102 are in open position.

[0023] When used as a disconnector, both contacts 101, 102 are connected to an end of the electrical circuit.

[0024] The vacuum switch according to the invention can be air-insulated or liquid insulated. In particular, because of the insulating case 3, 4, the vacuum switch 1 can be directly placed on the roof of the rolling stock for railway applications where said insulating case protects the switch from the external environment (dust, birds, soot, snow...). The vacuum switch according to the invention can be also placed inside a metal clad enclosed switchgear as a compact component for grounding or disconnecting. This is quite challenging with conventional grounding switch operating in air as they are not suitable to be placed in such enclosed switchgear.

[0025] To perform electrical grounding or disconnecting, and in particular for railway applications, the vacuum switch 1 according to the invention must fulfil the following necessary requirements:

- pass the BIL and Power Frequency tests for dielectric withstand voltages (examples of conditions required by these tests are BIL > 170 kV, PF > 75kV in case of 25kV VCB);
- withstand short circuit current in closed (i.e. grounding) position of the contacts for a specified time (for example, withstand 25kA for 1 second);
- maintain the contacts in closed position at high short circuit current;
- for disconnecting, carry the nominal current in closed position.

[0026] It is known from the electrical contact theory that the current flow between two electrical contacts passes through small contact spots. The microscopic current flow lines are restricted to a very small area at the interface of the contacts 101, 102. This current lines distribution generates repulsive or blow-off electromagnetic forces between the contacts that tend to blow the said contacts apart and prevent them to remain in closed position. Those electromagnetic blow-off forces F_b are proportional to the square of the flowing current.

[0027] On the other hand, it is known that contact resistance R_c is inversely proportional to the square root of the instantaneous closing force F_c. The instantaneous closing force F_c is the difference between the external force F_{ext} exerted by the actuating mechanism M and the external pressure (atmospheric pressure) while the contacts are in their closed position and the blow-off forces F_b :

$$F_c = F_{ext} - F_b \qquad (1)$$

[0028] The effect of this blow-off forces F_b is amplified in case of short circuit current and it increases remarkably the contact resistance, or in more severe conditions, it pushes the contacts apart. In order for the vacuum switch according to the invention to perform grounding or disconnecting safely, those blow-off forces F_b should be limited.

[0029] The macroscopic design of the contacts of the vacuum switch 1 according to the invention is adapted to cancel or reduce the effect of the blow-off forces F_b. The geometry of the contacts is shaped in such a way to alter the current path through said contacts in order to create electromagnetic attractive forces F_a to balance or to reduce the effect of the blow-off forces F_b. With these attractive forces F_a, the instantaneous closing force F_c can now be expressed as:

$$F_c = F_{ext} + F_a - F_b \qquad (2)$$

with the added condition that $F_c > 0$, since it is required that the contacts remain in closed position even during short circuit events (grounding or disconnecting).

[0030] Figures 2 to 11 illustrate different embodiments of the vacuum switch 1 according to the present invention with different possible geometries of the movable and fixed contacts 102, 101 which can create attractive forces F_a to satisfy equation (2) above.

[0031] In the first embodiment and its variants illustrated in figures 2 to 5, the movable and fixed contacts 102, 101 present a so called "frontal closing" geometry. In this first embodiment, the fixed contact 101 presents a trumpet shaped hollow 103 at its free end. The contact surface 105 of the fixed contact 101 is flat but has an opening 107 communicating with the said hollow 103. Similarly, the movable contact 102 has a trumpet shaped free end with a neck 104, a flange 106 and a flat contact surface 108 designed to come in contact with the contact surface 105 of the fixed contact 101. Preferably, there is a mechanical support element 110 around the neck 104 of the movable contact 102. This support element 110 is preferably made of stainless steel.

[0032] In a first variant of this first embodiment illustrated in figures 3a to 3c, there is a spring 109 inside the hollow 103 of the first contact 101 and placed directly under the opening 107. The spring 109 can be made of stainless steel and prevents the hollow 103 from collapsing on itself during closing of the contacts 101, 102. Another way to reinforce the hollow 103 of the fixed contact 101 is to provide a spring washer 111 inside the hollow 103 as pictured in the variant of figure 5.

[0033] In the second variant of the first embodiment illustrated in figures 4a and 4b, the contact surface 108 of the movable contact further comprises rims 108' at its periphery designed to come into contact 102 with the contact surface 105 of the fixed contact 101, while the said contact surface 105 of the fixed contact 101 comprised rims 105' around the opening 107 of the hollow 103 designed to come into contact with the contact surface 108 of the movable contact 102. Hence, in this variant, while in their closed position (figures 4b, 4c and 5) the contact between the fixed and movable contacts 101 and 102 is limited to the rims 108' and 105'. This helps to better alter and conduct the current flow I through the contacts in their closed position.

[0034] As illustrated in figures 3c and 4c, with the geometry according to the first embodiment, the current flow I in the contacts in their closed position is altered and attractive electromagnetic forces F_a are created that can balance or reduce the effect of the blow-off forces F_b.

[0035] In this first embodiment, the gap G between the contacts 101, 102 is preferably greater than the required clearance distance. For example, a gap of 16mm is enough to fulfil the requirement of a 25kV grounding switch or disconnector used in a railway application (for example, such a requirement can be BIL > 170kV and PF>75kV). In this embodiment also, the stroke for the movable contact 102 to come in closed position is equal to the gap G. Hence, with this first embodiment, it is possible to get a very compact air or liquid-insulated grounding switch or disconnector much more compact than a known air-insulated grounding switch for which the clearing distance and hence the stroke distance are very large (generally around 200 mm).

[0036] In the second embodiment of the vacuum switch 1 according to the invention, the contacts present a geometry called "tulip closing" as illustrated in figures 6 and 7a to 7b. In this second embodiment, the free end of the movable contact 102 has an essentially cylindrical shape with preferably a rounded contact surface 112 and is designed to be inserted into a corresponding recess 113 of the free end of the fixed contact 101. The recess 113 has thus a similar cylindrical shape with a concave rounded bottom 117. Preferably, the wall of the recess 113 of the fixed contact 101 is resilient to ensure easy insertion of the movable contact 102 into said recess 113 and electrical contact as soon as the movable contact 102 touches the wall of the fixed contact 101. As pictured in figures 6, 7a and 7b, the wall of the recess 113 is preferably made of a plurality of flexible lugs 115.

[0037] As illustrated in figure 7b, with this second embodiment, the current flow I in the contacts 101, 102 in their closed position is altered and attractive forces F_a are created from the fixed contact 101 which "clamp" via the plurality of flexible lugs 115 the movable contact 102 inside the recess 113 of the fixed contact 101. These attractive forces F_a - or pinching forces in this embodiment - can greatly balance and overcome the effect of the blow off forces F_b.

[0038] Because the fixed and movable contacts 101, 102 are overlapping, the vacuum switch according to the second embodiment offers a very secure closing.

[0039] In this second embodiment, the gap G between the contacts 101, 102 is also preferably greater that the required clearance distance. As with the first embodiment, a gap of 16mm is enough to fulfil the requirement of a 25kV grounding switch or disconnector used in a railway application. However, with this second geometry, the matching stroke for the movable contact 102 to come in closed position inside the recess 113 of the fixed contact 101 will be longer than the gap G. For example, as pictured in figure 6, for a 16mm gap G, the stroke is 25 mm. Still, the vacuum switch according to the second embodiment of the invention used as a grounding switch or disconnector remains more compact than most of the known air-insulated grounding switches with a stroke of 200 mm.

[0040] In the third embodiment illustrated in figure 8 to 11, the fixed and movable contacts 101, 102 present a so called "conic closing" geometry. In this third embodiment, the movable contact 102 has an "arrow" shaped free end with a neck 104 terminated by an inverted cone 114. This inverted cone 114 is designed to be inserted into a corresponding recess 113 of the free end of the fixed contact 101. As in the first embodiment, the fixed contact 101 also presents a hollow 103 under the recess 113 with an opening 107 linking the hollow 103 to the recess 113.

[0041] The inner wall of the recess 113 is the contact surface 105 of the fixed contact 101 designed to come into contact with the contact surface 108 of the movable contact 102 which is the outer wall of the inverted cone

114.

[0042] Preferably, there is a mechanical support element 110 around the neck 104 of the movable contact 102. This support element 110 is preferably made of stainless steel.

[0043] In a first variant of this third embodiment illustrated in figures 9a to 9c, there is a spring 109 inside the hollow 103 of the first contact 101 and placed directly under the opening 107. The spring 109 can be made of stainless steel and prevents the hollow 103 from collapsing on itself during closing of the contacts 101, 102. Another way to reinforce the hollow 103 of the fixed contact 101 is to provide a spring washer 111 inside the hollow 103 as pictured in the variant of figure 11.

[0044] In the second variant of the third embodiment illustrated in figures 10a to 10c, the contact surface 108 of the movable contact 102 further comprises rims 108' at its periphery designed to come into contact with the contact surface 105 of the fixed contact 101, while the said contact surface 105 of the fixed contact 101 comprised rims 105' around the opening 107 of the hollow 103 designed to come into contact with the contact surface 108 of the movable contact 102. Hence, in this variant, while in their closed position (figures 10b, 10c) the contact between the fixed and movable contacts 101, 102 is limited to the rims 108' and 105'. This helps better alter and conduct the current flow I through the contacts in their closed position.

[0045] As illustrated in figures 9c and 10c, with the geometry according to the third embodiment, the current flow I in the contacts in their closed position is altered and attractive electromagnetic forces F_a are created that can balance or reduce the effect of the blow-off forces F_b.

[0046] As in the other embodiments, in this third embodiment, the gap G between the contacts 101, 102 is preferably greater than the required clearance distance. For example, a gap of 16mm is enough to fulfil the requirement of a 25kV grounding switch or disconnector used in a railway application (for example, such a requirement can be BIL > 170kV and PF>75kV). However, with this third geometry, the matching stroke for the movable contact 102 to come in closed position inside the recess 113 of the fixed contact 101 will be longer than the gap G. Still, the vacuum switch according to the third embodiment of the invention used as a grounding switch or disconnector remains more compact than most of the known air-insulated grounding switches with a stroke of 200 mm.

[0047] As seen above, a vacuum switch according to the invention used for electrical grounding or as a disconnector can be very compact even more compact than a traditional vacuum switch used for current interruption as no arcing contacts are required. For example, the vacuum switch according to the invention used for grounding or disconnecting in railway applications can have a very small total diameter of 60 mm or under.

[0048] There are more advantages stemming from the use of a vacuum switch according to the invention as a grounding switch or disconnector. Though, the vacuum switch according to the invention uses the same basic principle as a traditional vacuum switch, it is not required to interrupt the current or to close under load when used as a grounding switch or as a disconnector. Hence, the overall design of the vacuum switch according to the invention can be more simple and cost effective than a traditional vacuum switch.

[0049] As seen above, the geometry of the contacts can be quite simple. While the grounding switch requirements mentioned above must be fulfilled, there is no need of a special geometry to generate transverse or axial magnetic field (TMF or AMF) to control the vacuum arc generated during opening of the contacts especially under short circuit conditions.

[0050] Expensive CuCr contacts are also not required, and more cost effective material can be used for the contacts instead. For example, the contacts can be made of copper or iron or one of copper and one of iron. Iron or any other ferromagnetic material can be used for one of the contact or both of them to enhance the attractive forces or pinching forces F_a between the contacts with all the geometries discussed above. For example, with the tulip closing geometry of the second embodiment described above, it has been found that a favourable configuration corresponds to a coper movable contact and an iron or ferromagnetic fixed contact with a tulip shape.

[0051] As previously mentioned, another advantage of using the vacuum switch according to the invention for grounding operation or as a disconnector stems from the fact that no arcing activity between the fixed and movable contacts 101, 102, is expected during opening of the contacts. Hence, the main shield 20 surrounding the contact area between the fixed and movable contacts 101, 102 can be removed or can be designed to only fulfil dielectric purposes. In this last case, it can therefore be made of cost effective material such as stainless steel.

[0052] Moreover, the insulating case of the vacuum switch according to the invention can be made of ceramic or glass ceramic, like traditional vacuum switch used for current breaking, but also simply of glass. The insulating case can be transparent (glass, ceramic or glass-ceramic) and with a transparent or semi-transparent main shield 20 or even no main shield at all, the operator can visually confirm the status of the vacuum switch (open or closed). Figure 13 illustrates such a grounding switch with a transparent insulating case and with a main shield 20 made as a quasi-transparent mesh of an appropriate material to form a Faraday cage which fulfils the required dielectric purposes (shaping the electric field and electric potential lines distribution when the contacts are in open position).

[0053] The vacuum switch according to the invention could also comprise any suitable detection mechanism capable of showing to the operator the state of the switch and the position of the contacts: open or closed. This could be useful in some applications, when for example the switch is placed inside metal-clad enclosed switchgear.

[0054] Figure 12 illustrates the use of a vacuum switch 1 according to the invention for electrical grounding in an electrical circuit for railway applications. The vacuum switch 1 is held within the frame 7 of the main circuit breaker of the electrical circuit. The actuating mechanism M and the external conductors 61, 62 attached to the movable contact 102 of the vacuum switch 1 and connected to the ground are in particular visible in this figure. In the closed position of the vacuum switch 1 according to the invention, the current flow through the external conductors 61, 62 can be used to provide added attractive forces F_{ca} between the fixed contact 101 and the movable contact 102 during short circuit.

[0055] In the closed position of the contacts, current flowing through the external conductors 61, 62 which are held in position by the push rod 63 of the actuating mechanism M provides more blow-on forces (attractive forces) F_{ca} which are repulsive forces between the conductors 61, 62, pushing these conductors 61, 62 away from each other. Consequently, these blow-on forces F_{ca} tend to keep the first and second contact 101, 102 in their closed position. These forces F_{ca} are, like the blow-off forces F_b, proportional to the square of the flowing current.

[0056] With these added attractive forces F_{ca}, the instantaneous closing force F_c can now be expressed as:

$$F_c = F_{ext} + F_a + \mathrm{F}_{\mathrm{ca}} - F_b \qquad (3)$$

with the added condition that $F_c > 0$, since it is required that the contacts remain in closed position even during short circuit events (grounding or disconnecting).

[0057] Figure 12 illustrates an example wherein the loop formed by the conductors 61, 62 is constrained by the mechanism box. When a short circuit current happens, the current in the loop provides the added attractive forces F_{ca} on the contacts. With this type of arrangement, only quite small, closed-contact spring forces are needed from the actuating mechanism M for satisfactory grounding operation even during full short-circuit currents.

[0058] In a variant, the vacuum switch according to the invention can be used alone or two or more of such vacuum switches can be used in series. Using two or more vacuum switch in series allows for a greater safety during operation since the total gap (distance to closed/open position of the extreme contacts) of such a series of vacuum switches is the sum of each gap of each vacuum switch in the series. Thus the gap between the contacts connected to each end of the circuit can be increased without the need to build a bigger and more expensive vacuum switch.

[0059] Generally speaking, the present invention provides a vacuum switch comprising an insulating case made of a suitable insulating material and closed at its end by two conducting caps to form a sealed vacuum chamber. Inside the sealed vacuum chamber, the vacuum switch comprises a first and a second contacts that are movable with respect to one another between a first open positon in which the contacts are not in contact and a second closed position in which the said contacts are in contact. The vacuum switch and in particular the first and second contacts are designed so as to remain in the closed position in case of a high short circuit current in the electrical circuit and passing through the vacuum switch. In particular, the vacuum switch and the contacts are designed so that the electromagnetic repulsive forces occurring between the first and the second contacts during a high short circuit current in the electrical circuit and passing through the vacuum switch while in closed position and tending to move the contacts away from each other are minimized or reduced.

[0060] Preferably, those electromagnetic repulsive forces are reduced by adapting the geometry of the first and second contacts to create electromagnetic attractive forces opposing said repulsive forces and tending to push the contacts together in their closed position.

[0061] The resulting vacuum switch can be used as a grounding switch or a as disconnector and is highly reliable, compact, durable and cost-effective since it does not require expensive material needed to withstand opening or closing under load as in a vacuum switch used to break the current in an electrical circuit. Moreover, the vacuum switch according to the invention can be used as an air or liquid-insulated grounding or disconnecting switch in the main electrical circuit and particularly for railway applications: the insulated case of the vacuum switch according to the invention provides a good protection against the harsh environmental conditions found on top of the rolling stock which makes the grounding switch durable.

Claims

1. Vacuum switch (1) comprising an insulating case (3, 4) made of a suitable insulating material, two conducting caps (51, 52) each securely fixed at an opening of the insulating case (3, 4) to form a sealed vacuum chamber (2) and a first contact (101) and a second contact (102) inside the sealed vacuum chamber (2) and movable with respect to one another between an open positon in which the first and second contacts (101, 102) are not in contact and a closed position in which the first and second contacts (101, 102) are in contact, **characterised by** the fact that the vacuum switch and the first and second contacts (101, 102) are designed so as to remain in the closed position in case of a high short circuit current passing through the said contacts (101, 102) when they are in the closed position.

2. Vacuum switch (1) according to claim 1, **characterised by** the fact that the first and second contacts (101, 102) are designed so that the electromagnetic repulsive forces (F_b) occurring between the said con-

tacts (101, 102) during a high short circuit current passing through said contacts (101, 102) while in the closed position and tending to move the said contacts (101, 102) away from each other are minimized or counterbalanced.

3. Vacuum switch (1) according to any one of the preceding claims, **characterised by** the fact that the first and second contacts (101, 102) are designed so that electromagnetic attractive forces (F_a) are created between the said contacts (101, 102) during a high short circuit current passing through said contacts (101, 102) while in the closed position, these that electromagnetic attractive forces (F_a) tending to keep the contacts (101, 102) in the closed position.

4. Vacuum switch (1) according to any of the preceding claims, **characterised by** the fact that the first contact (101) presents a trumpet shaped hollow (103) at its free end with a flat contact surface (105) having a hole (107), said hole (107) communicating with the hollow (103) while the second contact (102) presents a corresponding trumpet shaped free end having a neck (104), a flange (106) and a flat contact surface (108) designed to come in contact with the contact surface (105) of the first contact (101) in the closed position.

5. Vacuum switch (1) according to claim 4, **characterised by** the fact that there is an elastic element (109, 111) inside the hollow (103) to prevent the said hollow from collapsing upon closing of the contacts (101, 102).

6. Vacuum switch (1) according to claim 4 or 5, **characterised by** the fact there is a support element (110) around the neck (104) of the second contact (102).

7. Vacuum switch (1) according to any one of claims 1 to 3, **characterised by** the fact that the free end of the second contact (102) is essentially cylindrical or conical and the first contact (101) presents at its free end a recess (113) designed to receive the free end of the second contact in the closed position.

8. Vacuum switch (1) according to the preceding claim, **characterised by** the fact that the recess (113) of the first contact (101) has a resilient wall made of a plurality of flexible lugs (115).

9. Vacuum switch (1) according to any one of the preceding claims, **characterised by** the fact the contact surface between the contacts (101, 102) in their closed position is limited to rims (105', 108') present on each free end of the first and second contacts (101, 102).

10. Vacuum switch (1) according to any of the preceding claims, **characterised by** the fact that the insulating case (3, 4) is made of ceramic, glass-ceramic or glass.

11. Vacuum switch (1) according to the preceding claim, **characterised by** the fact that the insulating case (3, 4) is transparent.

12. Vacuum switch (1) according to any of the preceding claims, **characterised by** the fact that either both or one of the first and second contacts (101, 102) are made of copper, iron or any other ferromagnetic material.

13. Vacuum switch (1) according to any of the preceding claims, **characterised by** the fact that it further comprises a main shield (20) positioned inside the sealed vacuum chamber (2) around the first and second contacts (101, 102), said main shield (20) being designed as a quasi-transparent mesh through which the position of the first and second contacts (101, 102) is visible.

14. Use of the vacuum switch (1) according to any of the preceding claims, as an air or liquid-insulated grounding switch or as a disconnector for railway applications.

15. Electrical circuit comprising a vacuum switch (1) according to any of the claims 1 to 14, **characterised by** the fact that the second contact (102) is connected to the ground via at least two conductors (61, 62) arranged in a loop, and by the fact that the length of the conductors (61, 62) and the distance between the said conductors (61, 62) are adjusted so that in the closed position of the contacts (101, 102) of the vacuum switch (1), secondary attractive forces (F_{ca}) are generated by the current flowing through the vacuum switch (1) and the conductors (61, 62) that tend to push the conductors (61, 62) away from each other and thus tend to keep the first and second contacts (101, 102) in their closed position during a short circuit current in the electrical circuit.

Fig.1

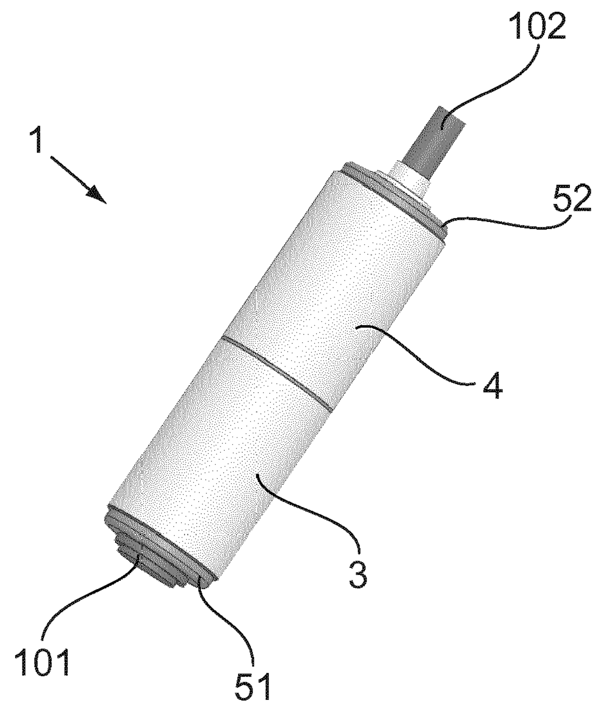


Fig.2

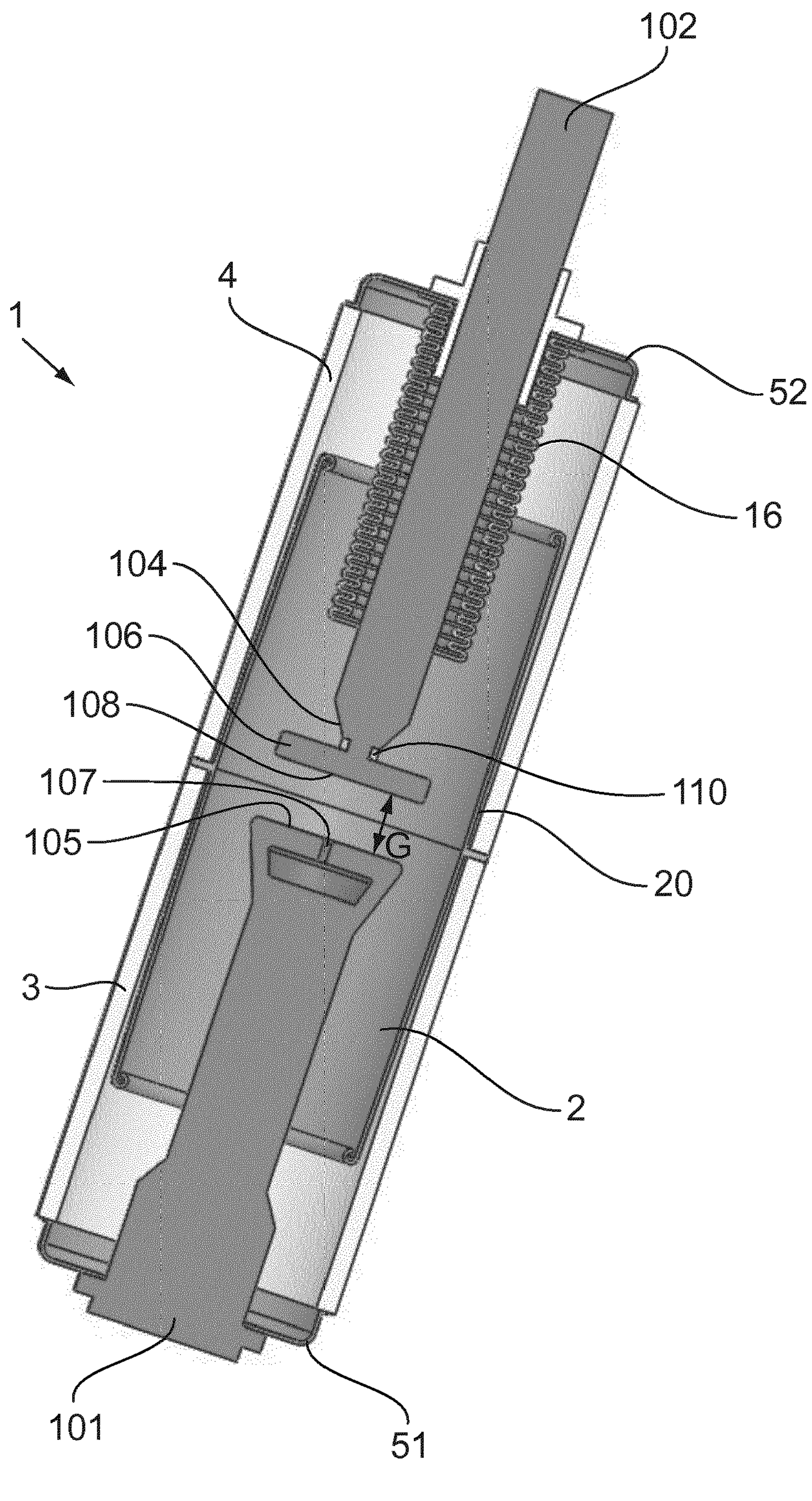


Fig.3a

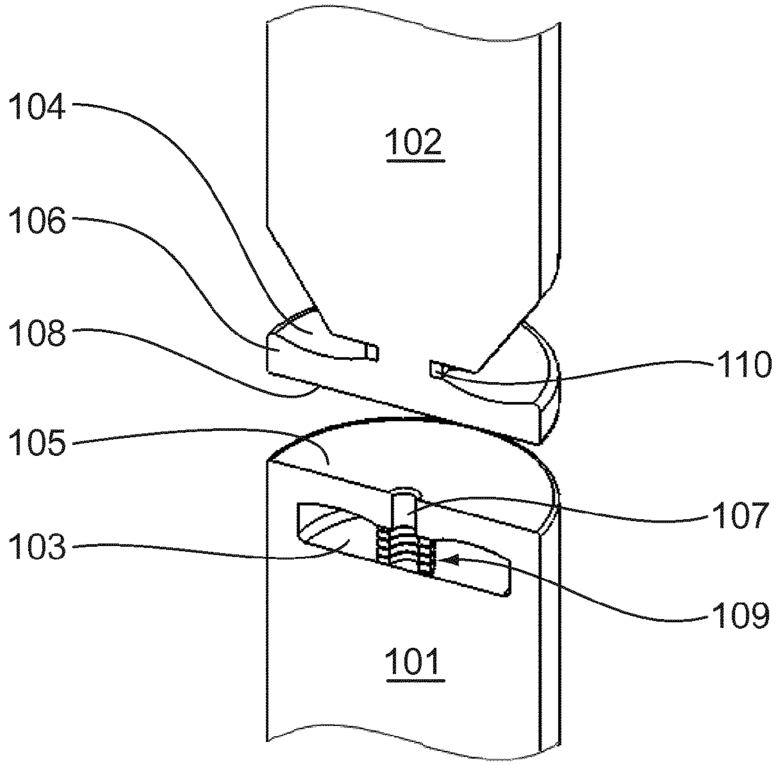
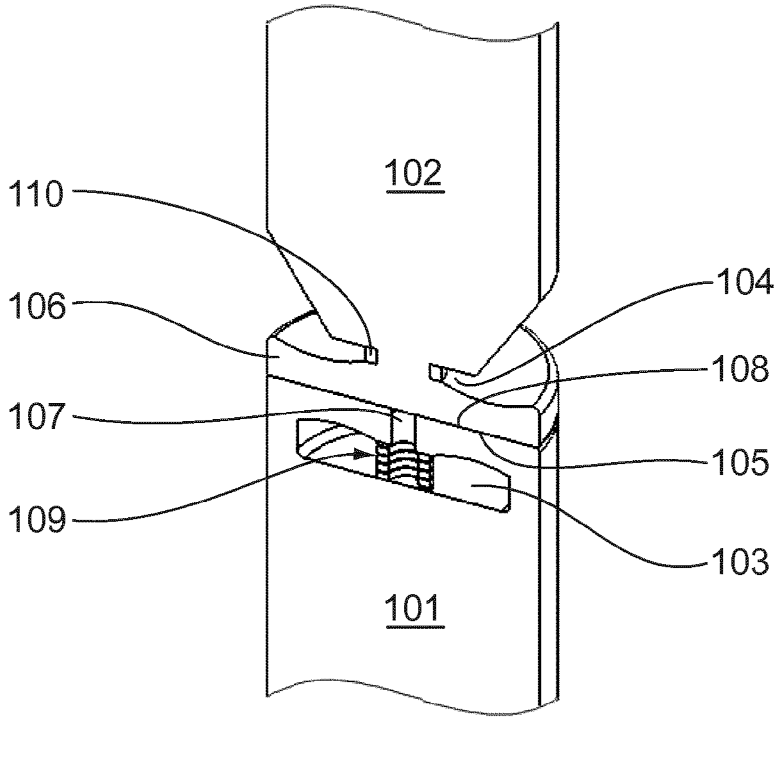

104
106
108
105
103
102
110
107
109
101

Fig.3b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106
107
109
102
104
108
105
103
101

Fig.3c

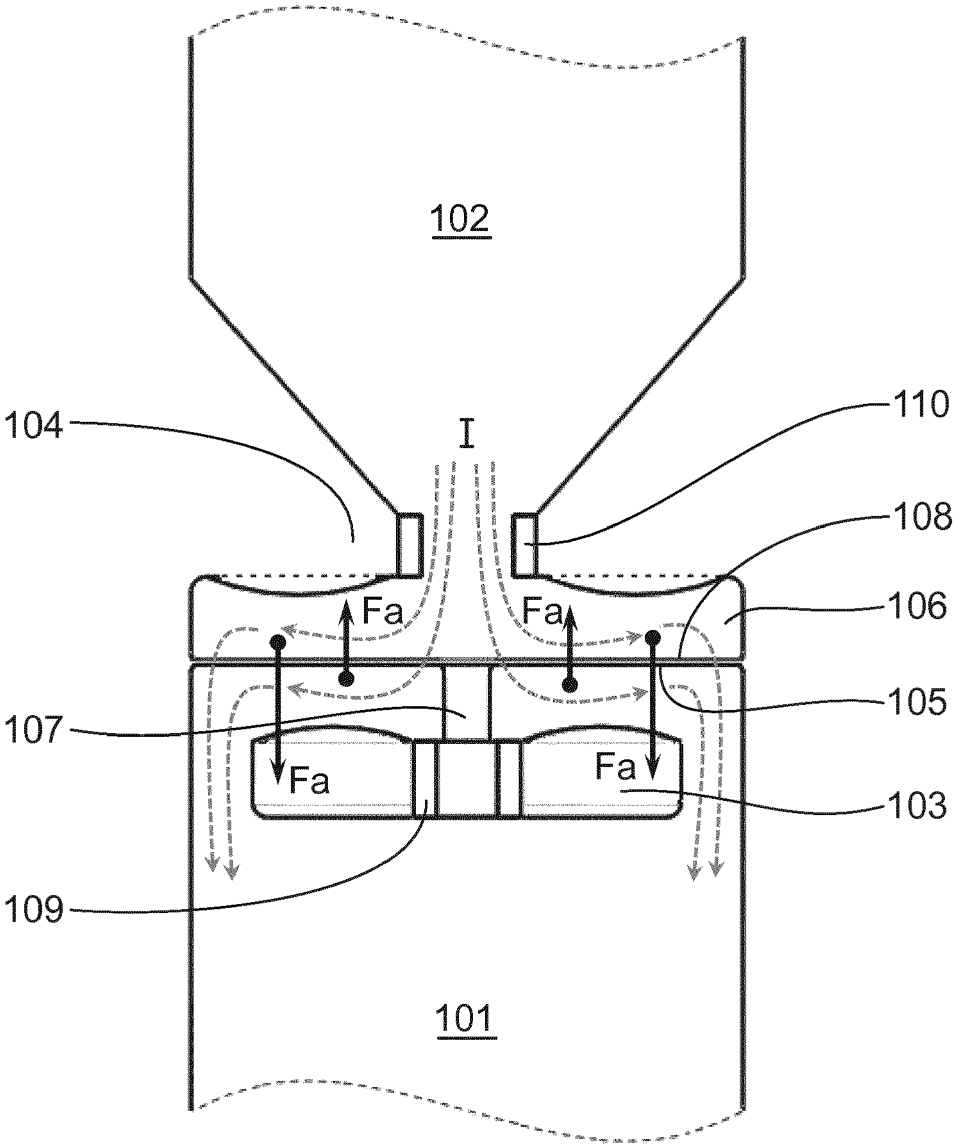
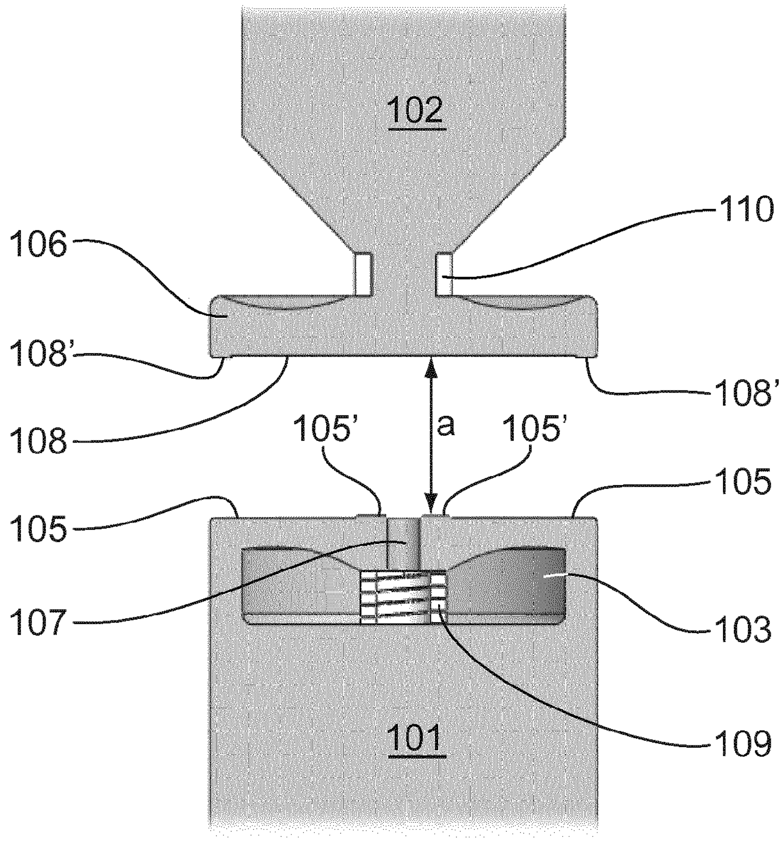


Fig.4a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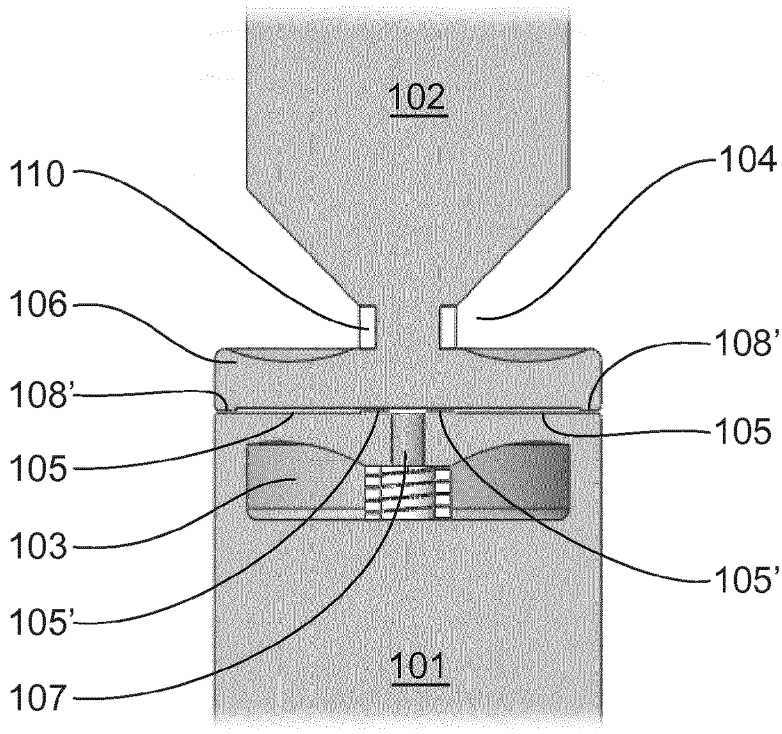
110
106
108'
108'
108
105'
a
105'
105
105
107
103
109
101

Fig.4b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110
104
106
108'
108'
105
105
103
105'
105'
107
101

Fig.4c

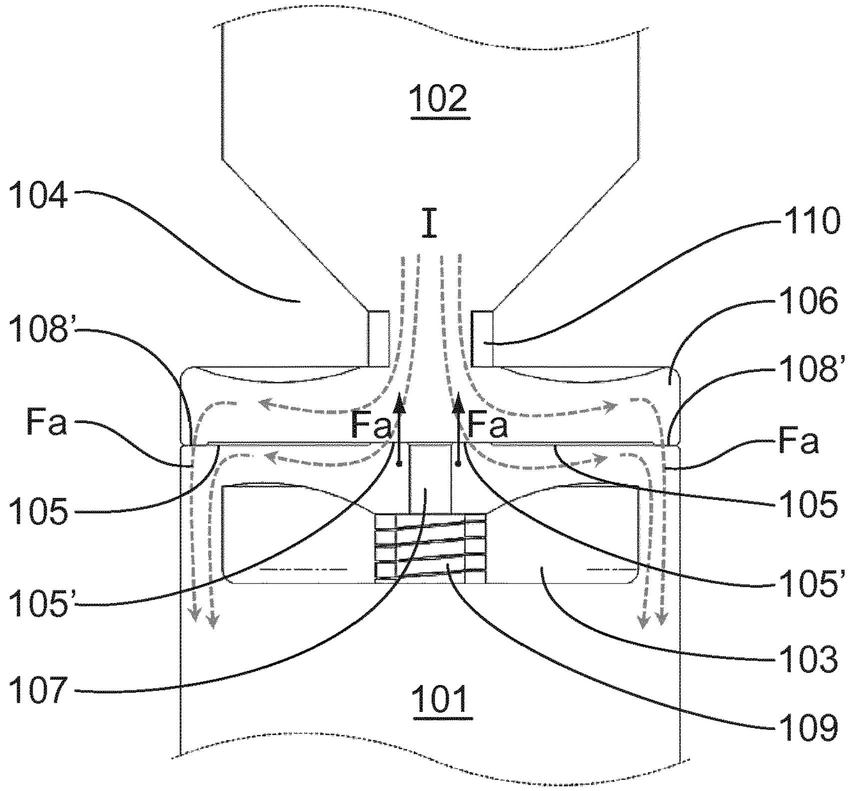
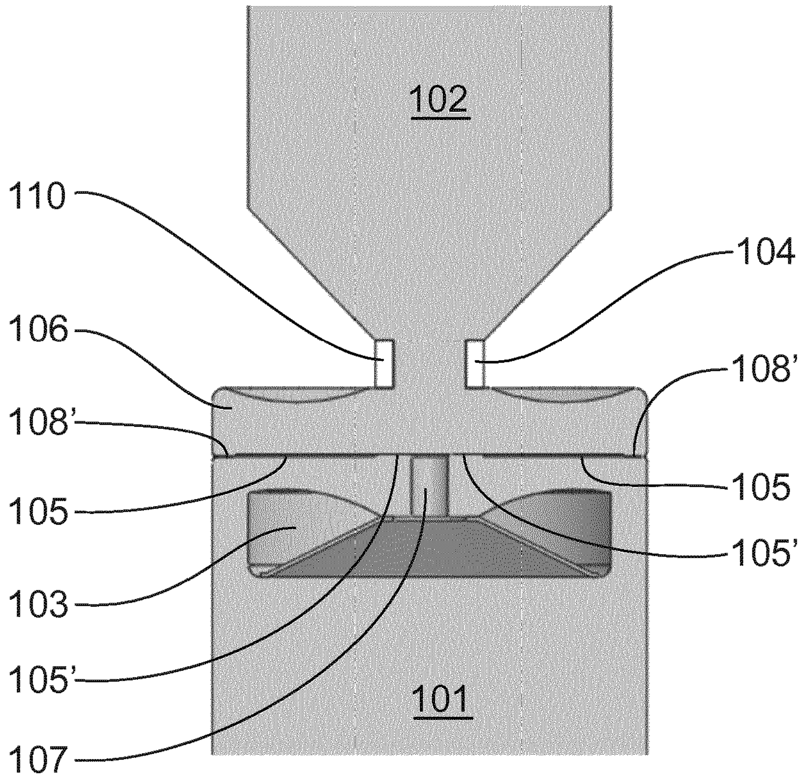

102
I
104
110
106
108'
108'
Fa
Fa
Fa
Fa
105
105
105'
105'
103
107
101
109

Fig.5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110
104
106
108'
108'
105
105
105'
103
105'
107
101

Fig.6

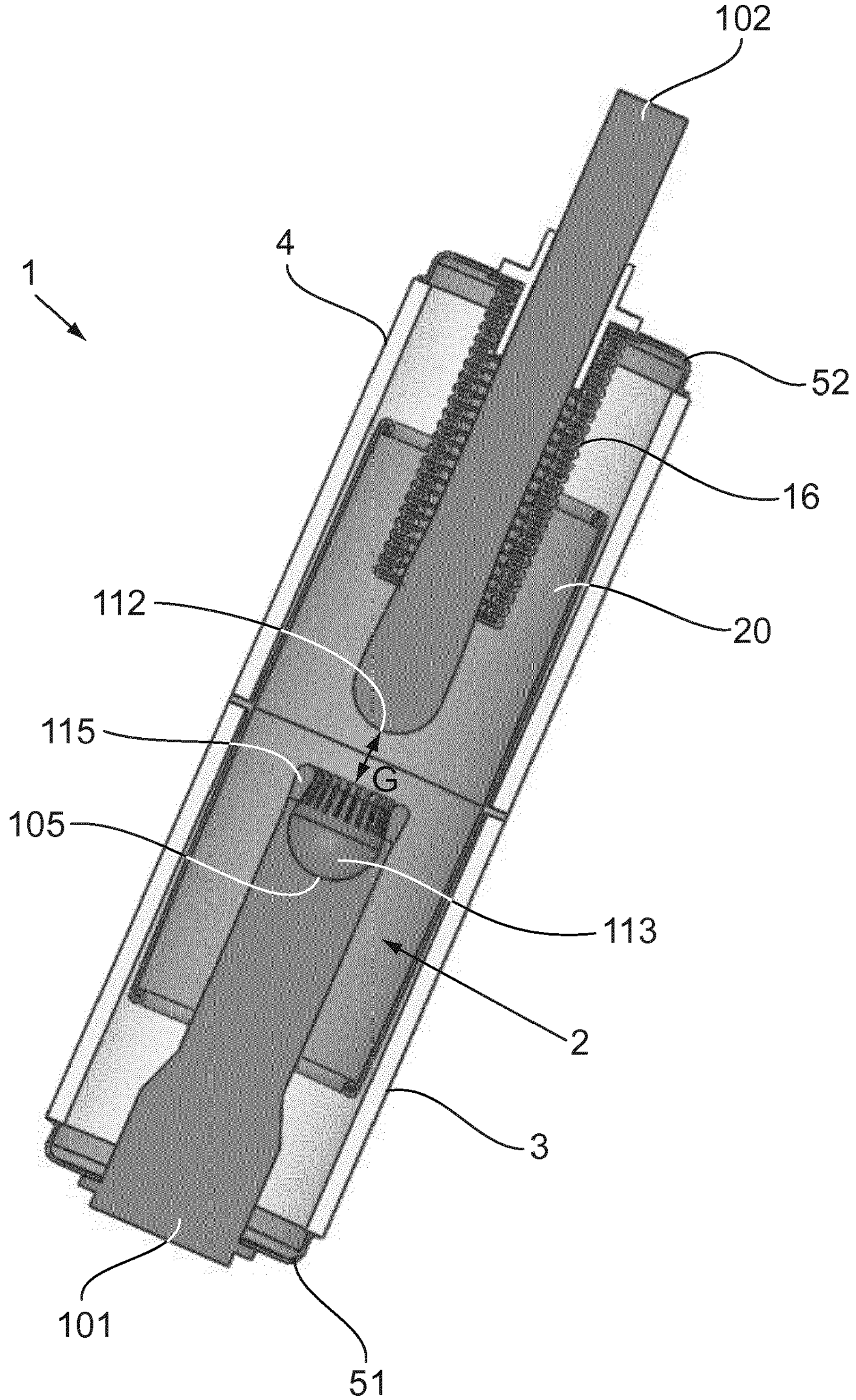


Fig.7a

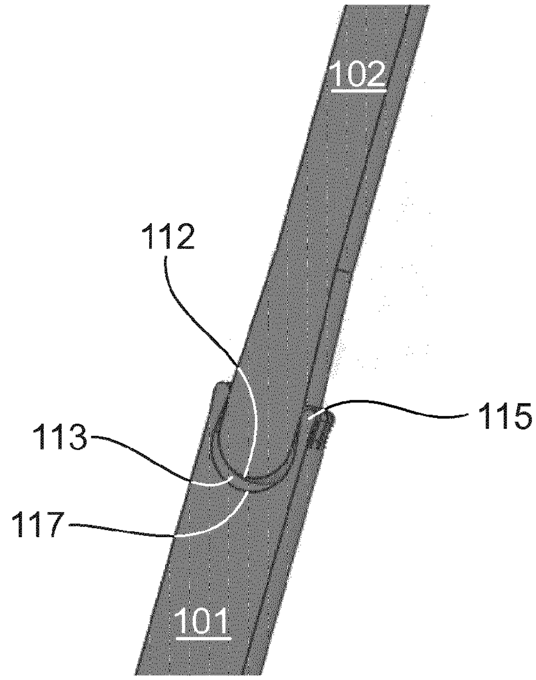


Fig.7b

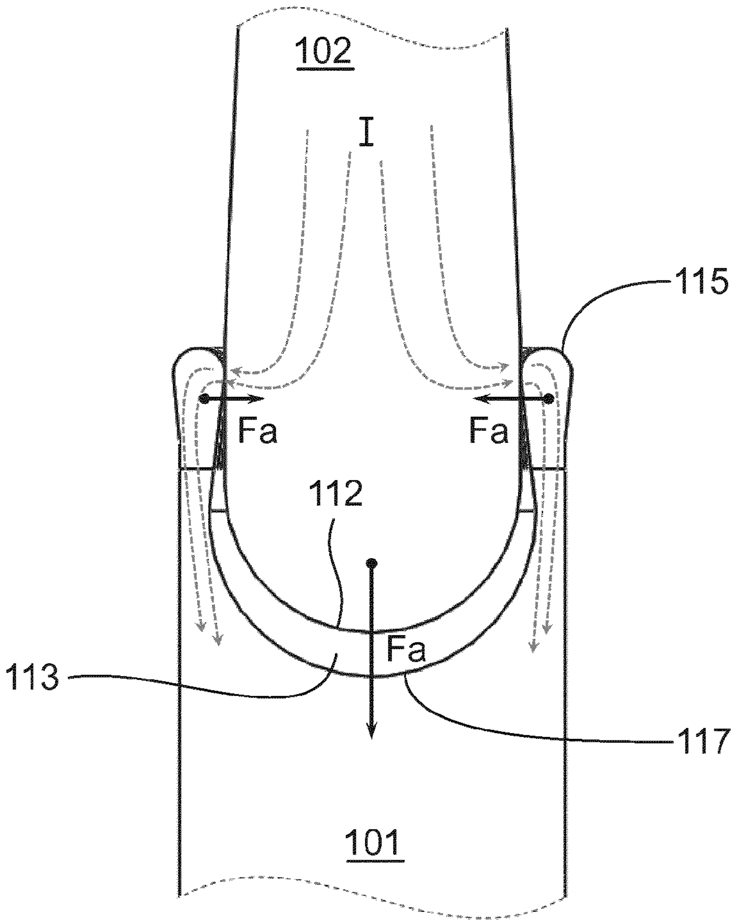


Fig.8

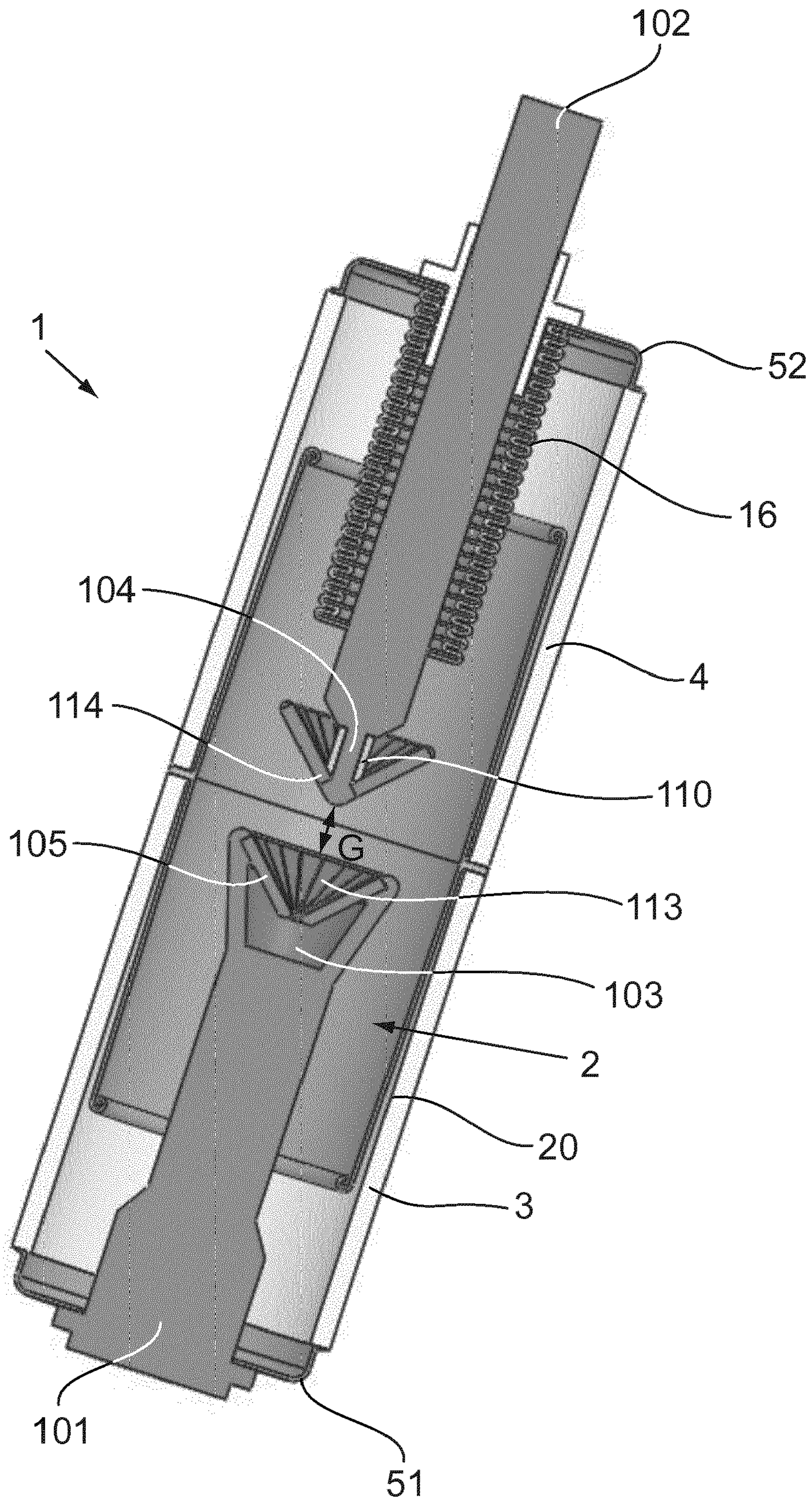


Fig.9a

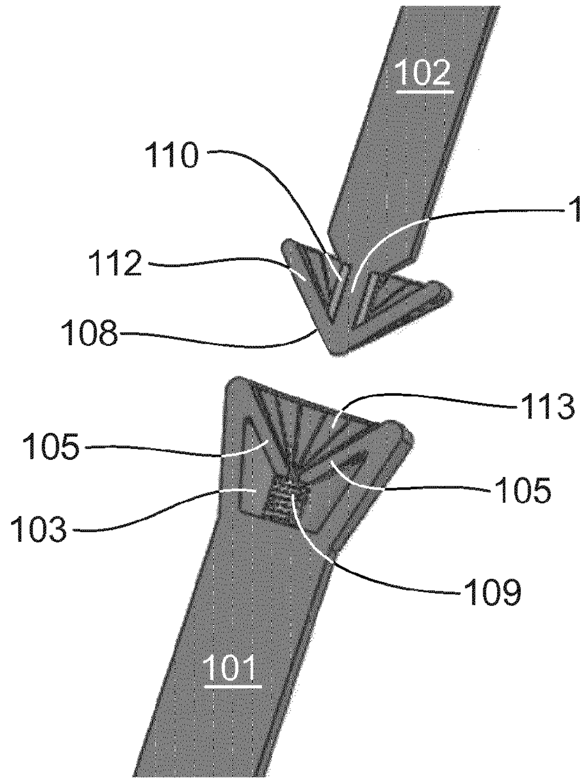


Fig.9b

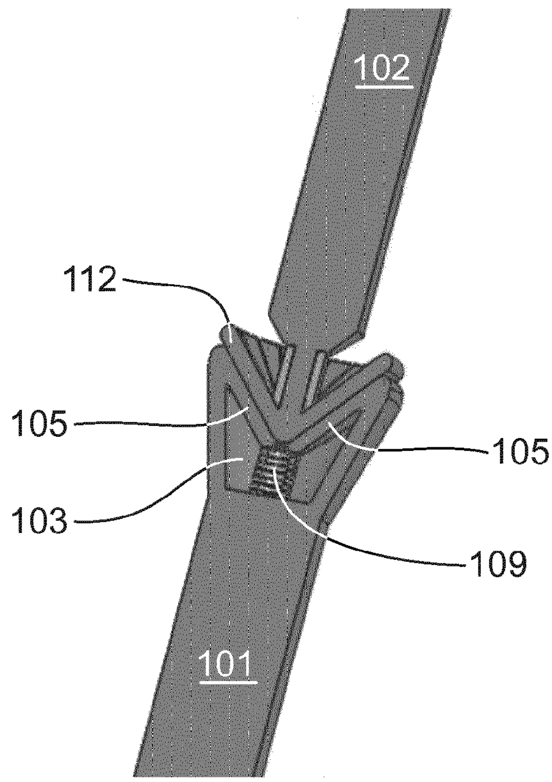


Fig.9c

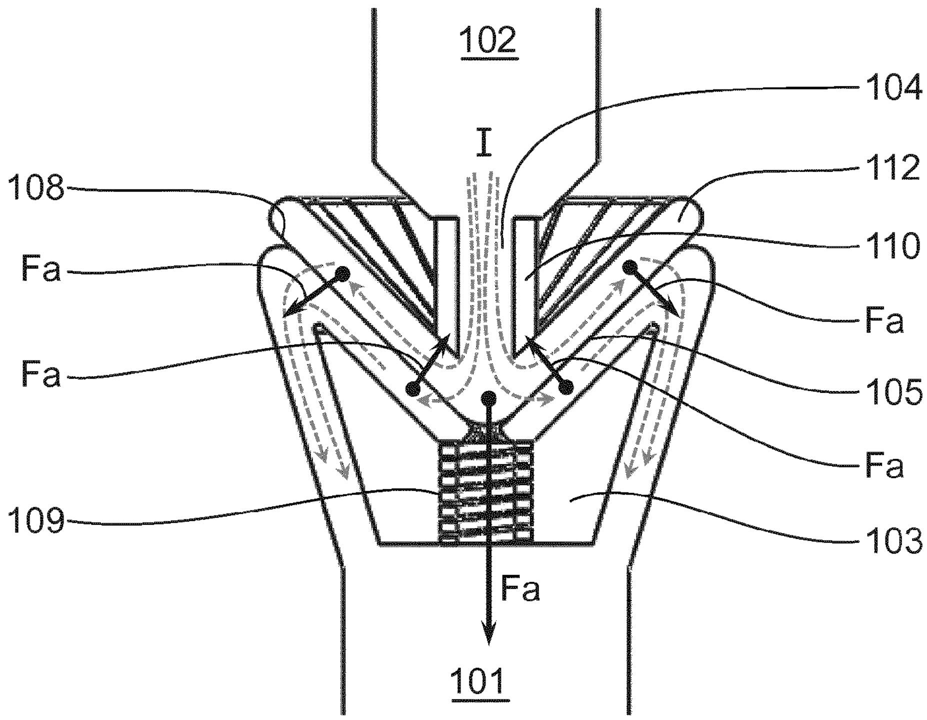


Fig.10a

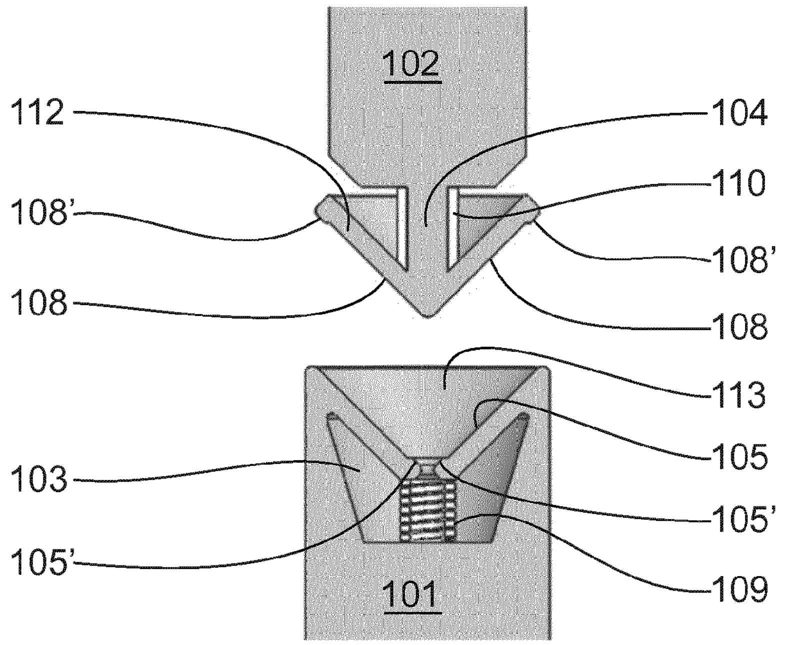


Fig.10b

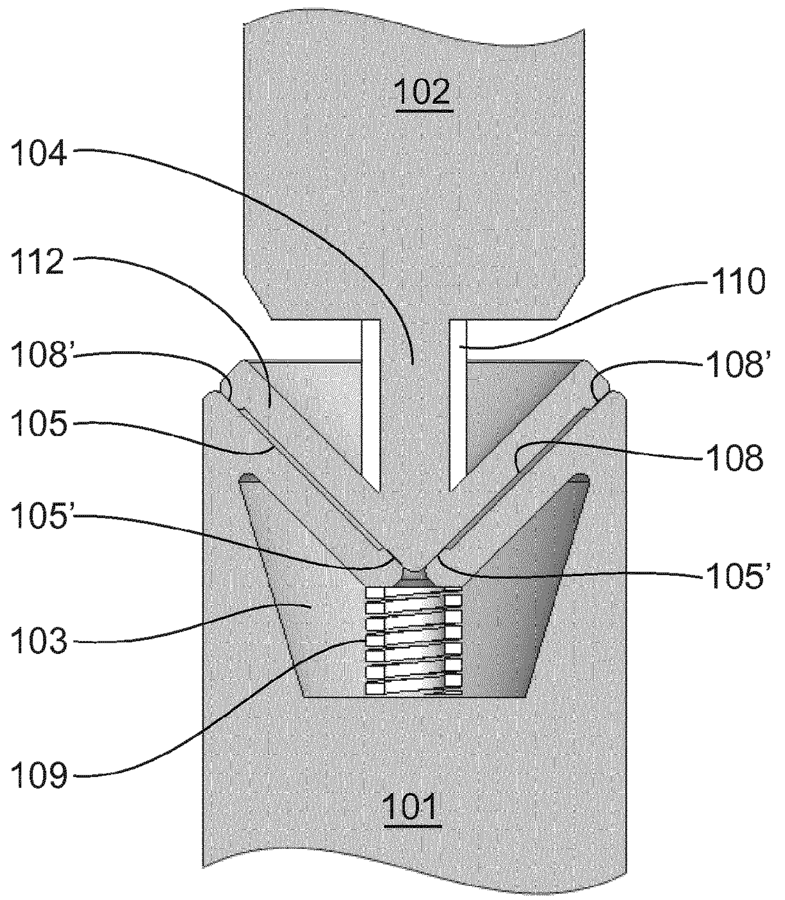


Fig.10c

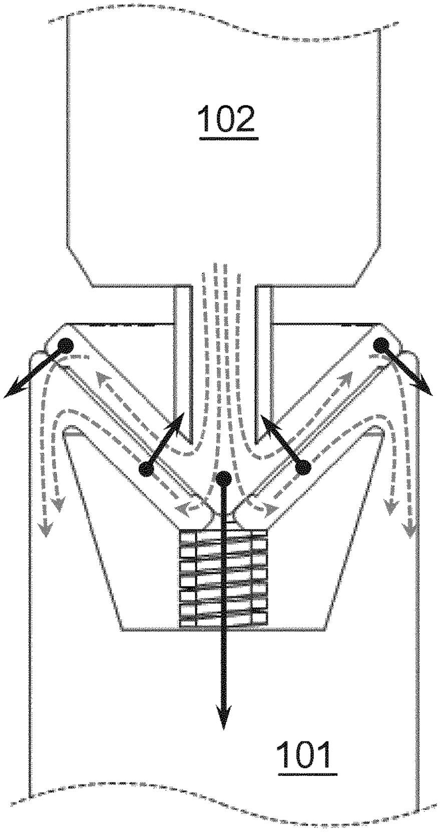


Fig.11

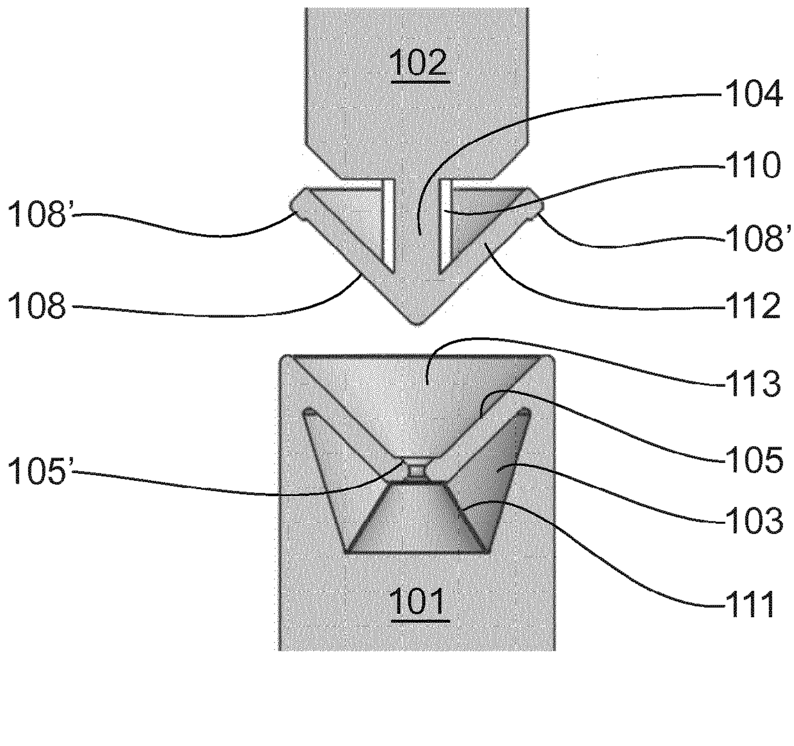


Fig.12

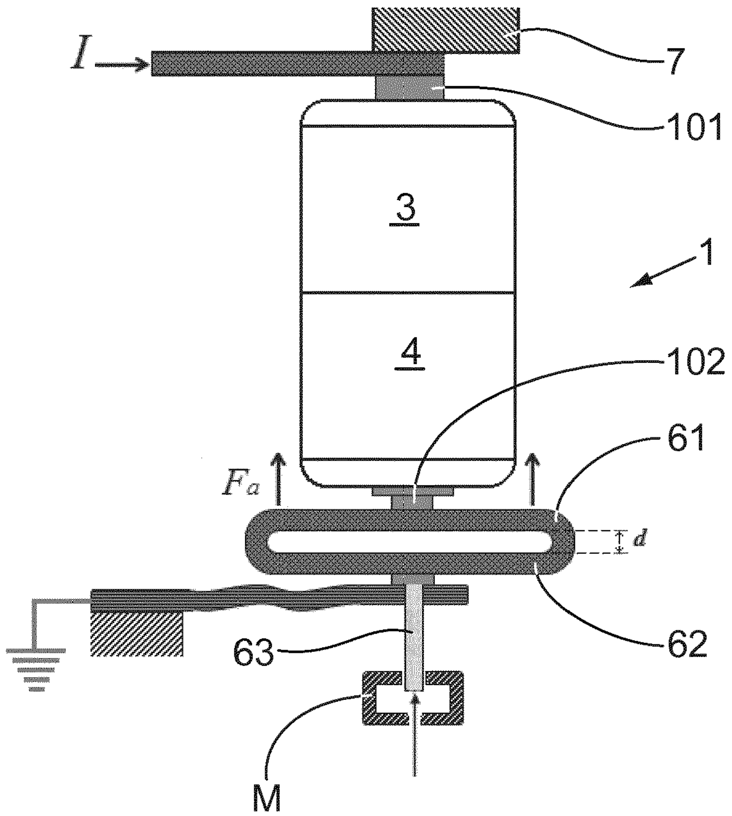
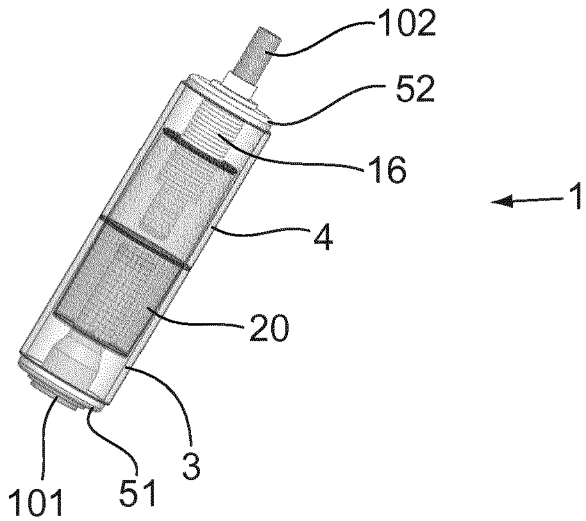


Fig.13



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EUROPEAN SEARCH REPORT

Application Number
EP 17 16 1547

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y A	CN 106 252 151 A (BEIJING SOJO ELECTRIC CO LTD) 21 December 2016 (2016-12-21) * paragraphs [0033], [0046], [0048] * * figures * -----	1-3,7,8,10-14 15 4-6,9	INV. H01H1/54 H01H33/664
Y	DE 11 55 186 B (BBC BROWN BOVERI & CIE) 3 October 1963 (1963-10-03) * the whole document * -----	15	

TECHNICAL FIELDS SEARCHED (IPC)

H01H

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 September 2017	Ledoux, Serge

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20-09-2017

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DE 1155186 B	03-10-1963	NONE	

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