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(54) A SWITCHING APPARATUS FOR ELECTRIC POWER DISTRIBUTION GRIDS

(57) A switching apparatus for electric power distribution grids comprising:
- one or more electric poles;
- for each electric pole, at least a fixed contact and a movable contact, said movable contact being reversibly movable between a coupled position, at which said movable contact is coupled to said fixed contact, and an uncoupled position, at which said movable contact is separated from said fixed contact;
- for each electric pole, an arc-breaking assembly comprising a plurality of arc-breaking plates arranged side by side and spaced one from another;

Said arc-breaking assembly comprises shielding means of electrically insulating material operatively coupled to said fixed contact and to said arc-breaking plates.

Said shielding means partially cover surfaces of said fixed contact and said arc-breaking plates, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

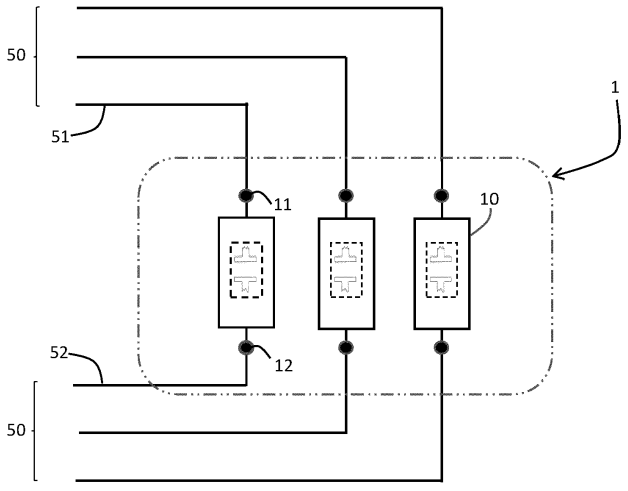


FIG. 1

EP 3 933 866 A1

Description

[0001] The present invention relates to a switching apparatus for electric power distribution grids, in particular for medium-voltage electric systems.

[0002] Switching apparatuses for electric power distribution grids (e.g. gas-insulated circuit breakers) comprise one or more electrical poles, each including electric contacts that can be mutually coupled or uncoupled.

[0003] As is known, during an opening operation of the switching apparatus, electric arcs may occur between the above-mentioned electric contacts under separation, particularly when high line currents (e.g. overload currents or short-circuit currents) are interrupted.

[0004] In order to efficiently interrupt the current passing through the electric poles, such electric arcs have to be extinguished as quickly as possible. To this aim, switching apparatuses often comprise an arc-breaking assembly positioned in proximity of the electric contacts of each electric pole.

[0005] An arc-breaking assembly typically includes a stack of arc-breaking plates made of a metallic ferromagnetic material and arranged spaced one from another.

[0006] When the electric contacts of the electric pole separate, the resulting electric arcs are driven to the arc-breaking plates, which favour the quench of the electric arcs by splitting these latter in smaller portions between adjacent arc-breaking plates.

[0007] Although switching apparatuses provided with arc-breaking plates generally perform their functionalities in a rather satisfying way, there is still the need for some improvements, particularly to make more efficient the arc-quenching process when the switching apparatus operates at relatively high operating voltages. Such a demand appears even more important as insulating gases having lower global warming potential but weaker dielectric properties with respect to SF6 are increasingly used in switching apparatuses.

[0008] Nowadays, there are available switching apparatuses (self-blast circuit breakers) including arc-chambers provided with nozzle arrangements made of a plastic material (PTFE), which favour the arc-quenching process by causing local overpressures of the insulating gas during arching phenomena and by employing the ablation of plastic material at hot temperatures. These solutions, however, are rather expensive to carry out at industrial level and they are generally adopted in arc-chambers of the "puffer" type, which do not employ arc-breaking plates.

[0009] The main aim of the present invention is to provide a switching apparatus for electric power distribution grids that allows overcoming the drawbacks of the known art.

[0010] Within this aim, a purpose of the present invention is to provide a switching apparatus having electric poles provided with an arc-breaking assembly equipped with arc-breaking plates, which is capable of providing an effective arc-quenching process even when the switching apparatus operates at relatively high operating voltages.

[0011] A further purpose of the present invention is to provide a switching apparatus, which shows improved commutation efficiency during an opening manoeuvre.

[0012] A further purpose of the present invention is to provide a switching apparatus, which is relatively simple and cheap to be manufactured at industrial levels.

[0013] The above aim and purposes, as well as other purposes that will emerge clearly from the following description and attached drawings, are provided, according to the invention, by a switching apparatus for electric power distribution grids, according to the following claim 1 and the related dependent claims.

[0014] In a general definition, the switching apparatus, according to the invention comprises:

- one or more electric poles;
- for each electric pole, at least a fixed contact and a movable contact. The movable contact is reversibly movable between a coupled position, at which said movable contact is coupled to said fixed contact, and an uncoupled position, at which said movable contact is separated from said fixed contact;
- for each electric pole, an arc-breaking assembly including a plurality of arc-breaking plates. The arc-breaking plates are arranged side by side and spaced one from another. The arc-breaking plates are located in proximity of the fixed contact at positions having increasing relative distances with respect to said fixed contact.

[0015] According to the invention, the arc-breaking assembly comprises shielding means made of electrically insulating material (preferably a plastic material) operatively coupled to said fixed contact and to said arc-breaking plates. Said shielding means partially cover corresponding surfaces of the fixed contact and of the arc-breaking plates, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

[0016] Conveniently, said shielding means are configured in such a way to confine possible electric arcs, which may occur during an opening manoeuvre of said switching apparatus, at predefined paths extending between mutually facing conductive surface portions of said fixed contact and of said arc-breaking plates, which are not covered by said shielding means.

[0017] According to an aspect of the invention, said shielding means comprise one or more shaped inserts of electrically insulating material partially covering corresponding surfaces of said fixed contact and said arc-breaking plates, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

[0018] Preferably, said shielding means comprise one or more first inserts of insulating material. Said first inserts of electrically insulating material surround at least par-

tially the fixed contact and partially cover corresponding surfaces of said fixed contact, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

[0019] Preferably, said first inserts of electrically insulating material have shaped portions, which are interposed between the fixed contact and a first arc-breaking plate in proximal position with respect to said fixed contact. Additionally, said shaped portions partially cover corresponding surfaces of said first arc-breaking plate.

[0020] Preferably, said shielding means comprise one or more second inserts of electrically insulating material. Said second inserts of insulating material are interposed between adjacent arc-breaking plates and partially cover corresponding mutually facing surfaces of said adjacent arc-breaking plates.

[0021] Preferably, said shielding means comprise one or more third inserts made of electrically insulating material. Said third inserts of insulating material partially cover corresponding surfaces of a last arc-breaking plate in distal position with respect to said fixed contact. Preferably, said arc-breaking assembly comprises a shaped holder of electrically insulating material.

[0022] Preferably, the switching apparatus comprises at least an arc chamber including one or more fixed contacts, one or more movable contacts and one or more arc-breaking assemblies, said at least an arc chamber being filled with an insulating gas.

[0023] Further features and advantages of the present invention will be more apparent from the description of preferred but not exclusive embodiments of the present invention, shown by way of examples in the accompanying drawings, wherein:

- Figure 1 schematically represents a switching apparatus, according to the present invention;
- Figures 2-8 schematically show different views of an electric pole of the switching apparatus, according to some embodiments of the invention;
- Figures 9-12 schematically show an arc-breaking assembly of the switching apparatus, according to further possible embodiments of the invention;
- Figures 13-14 show test evidence concerning the behavior of arc-breaking plates included in an arc-breaking assembly of the switching apparatus, according to the invention.

[0024] With reference to the attached figures, the present invention relates to a switching apparatus 1 for electric power distribution grids.

[0025] The switching apparatus 1 is particularly adapted for AC medium-voltage electric systems and it will be described with particular reference to this kind of applications. However, in principle, it may be used also in electric systems of different types, e.g. DC medium-voltage electric systems or low-voltage electric systems.

[0026] For the purposes of the present invention, the term "low-voltage" (LV) relates to operating voltages lower than 1 kV AC and 1.5 kV DC whereas the term "medium-voltage" (MV) relates to operating voltages higher than 1 kV up to some tens of kV, e.g. 70 kV AC and 100 kV DC. Figure 1 shows a schematic view the switching apparatus 1.

[0027] The switching apparatus 1 comprises one or more electric poles 10, each comprising a pair of pole contacts 11, 12 that can be electrically coupled to corresponding line conductors 51, 52 of an electric line 50.

[0028] The line conductors 51, 52 of the electric line 50 are, in turn, electrically connectable to an equivalent electric power source (e.g. an electric power feeding or generation system or a section of electric grid) and to an equivalent electric load (e.g. an electric system or apparatus or a section of electric grid).

[0029] The number of electric poles 10 of the switching apparatus 1 may vary, according to the needs. In the embodiments shown in the cited figures, the switching apparatus 1 is of the three-phase type and it comprises three-electric poles. However, according to other embodiments of the invention (not shown), the switching apparatus 1 may include a different number of electric poles depending on the number of electric phases of the electric line 50.

[0030] According to the invention, the switching apparatus 1 comprises, for each electric pole 10, at least a pair of electric contacts 2, 3 that can be mutually coupled or decoupled in order to allow or interrupt the flow of a current through said electric pole.

[0031] In particular, the switching apparatus 1 comprises, for each electric pole 10, at least a fixed contact 2 and at least a movable contact 3.

[0032] According to some embodiments of the invention, the switching apparatus 1 comprises, for each electric pole 10, a single fixed contact and a single movable contact that can be mutually coupled or decoupled (single current breaking configuration).

[0033] According to other embodiments of the invention (not shown), the switching apparatus 1 comprises, for each electric pole 10, a pair of fixed contacts and a pair of movable contacts that can be mutually coupled or decoupled.

[0034] Each movable contact 3 of the switching apparatus is reversibly movable between a coupled position, at which it is coupled to the corresponding fixed contact 2, and an uncoupled position, at which it is separated from the corresponding fixed contact 2.

[0035] When each movable contact 3 is in a coupled position, the switching apparatus 1 is in a closed state and line currents can flow along the electric poles 10. Instead, when each movable contact 3 is in an uncoupled position, the switching apparatus 1 is in an open state and no line currents can flow along the electric poles 10.

[0036] A transition from a closed state to the open state forms an opening manoeuvre of the switching apparatus 1 whereas a transition from an open state to a closed state forms a closing manoeuvre of the switching apparatus 1.

[0037] According to possible embodiments of the invention, each fixed contact 2 and movable contact 3 may comprise a single contact blade or multiple contacts blades (figures 3, 4).

[0038] The fixed contact 2 has surfaces 200 exposed to possible electric arcs during an opening manoeuvre of the switching apparatus. If the fixed contact 2 includes a single blade, the above-mentioned exposed surfaces 200 are the external surfaces of the contact blade. If the fixed contact 2 includes multiple blades, the above-mentioned exposed surfaces 200 include the external surfaces and the mutually facing internal surfaces of the contact blades.

[0039] According to some embodiments of the invention (figure 2), each movable contact 3 reversibly moves between the above-mentioned coupled and uncoupled positions by carrying out suitable opposite rotational movements.

[0040] According to other embodiments of the invention (not shown), each movable contact 3 reversibly moves the above-mentioned coupled and uncoupled positions by carrying out suitable opposite linear movements.

[0041] Conveniently, the switching apparatus 1 comprises actuating means (not shown) operatively coupled to the movable contacts 3 through suitable motion transmission means (not shown) and adapted to actuate said movable contacts during an opening or closing manoeuvre.

[0042] In general, the electric contacts 2-3, the above-mentioned actuating means and the motion transmission means of the switching apparatus 1 may be realized according to solutions of known type and they will be described hereinafter in relation to the aspects of interest of the invention only, for the sake of brevity.

[0043] Besides, the switching apparatus 1 may comprise a variety of additional components (most of them are not shown in the cited figures), which may be realized according to solutions of known type. Also, these additional components will be not described hereinafter, for the sake of brevity.

[0044] The switching apparatus 1 comprises, for each electric pole 10, an arc-breaking assembly 4. The arc-breaking assembly 4 comprises a plurality of arc-breaking plates 40a, 40b, 40c arranged in proximity of the electric contacts 2-3.

[0045] The arc-breaking plates 40a, 40b, 40c are conveniently stacked side by side and spaced one from another along a given stack direction, which is conveniently oriented according to the trajectory of the movable contact 3 during the manoeuvres of the switching apparatus.

[0046] The arc-breaking plates 40a, 40b, 40c are thus arranged at positions having increasing relative distances with respect to the fixed contact 2.

[0047] Obviously, the arc-breaking plates 40a, 40b, 40c are oriented perpendicularly with respect to the trajectory plane of the movable contact 3, during the manoeuvres of the switching apparatus. Preferably, the arc-breaking assembly 4 comprises a first arc-breaking plate 40a in proximal position with respect to the fixed contact 2, a last arc-breaking plate 40c in distal position with respect to the fixed contact 2 and one or more intermediate arc-breaking plates 40b arranged between the first and last arc-breaking plates 40a, 40b.

[0048] Each arc-breaking plate 40a, 40b, 40c has opposite surfaces 400, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

[0049] The exposed surfaces 400 are oriented perpendicularly with respect to the trajectory plane of the movable contact 3, during the manoeuvres of the switching apparatus.

[0050] Since the arc-breaking plates 40a, 40b, 40c basically have a planar geometry, each pair of opposite surfaces 400 defines the thickness of the corresponding arc-breaking plate. Obviously, as they are arranged in a stacked configuration, adjacent arc-breaking plates 40a, 40b, 40c have mutually facing surfaces 400 defining suitable the intermediate gaps between them.

[0051] In general, each arc-breaking plate 40a, 40b, 40c comprises opposite first (bottom) and second (top) sides 401, 402 defining a first dimension (for example the length L) of said plate and opposite third and fourth (lateral) sides 403, 404 defining a second dimension (for example the width W) of said plate.

[0052] In principle, the arc-breaking plates 40a, 40b, 40c may be shaped according to the needs.

[0053] As an example (figure 5), each arc-breaking plate may have a substantially rectangular shape (e.g. with rounded edges). In this case, each arc-breaking plate 40a, 40b, 40c comprises substantially rectilinear sides defining its boundaries.

[0054] As a further example (figure 6), each arc-breaking plate may have substantially a T-like shape (e.g. with rounded edges). In this case, each arc-breaking plate 40a, 40b, 40c comprises contoured sides defining its boundaries.

[0055] Preferably, the arc-breaking plates 40a, 40b, 40c have the first and second sides 401, 402 respectively in a proximal position and in a distal position with respect to the movable contact 3, in particular during a manoeuvre of the switching apparatus.

[0056] Preferably (figures 5-6), at their first side 41, the arc-breaking plates 40a, 40b, 40c comprises a groove 410 through which the movable contact 3 passes, during a manoeuvre of the switching apparatus. In practice, when a manoeuvre is carried out, the movable contact 3 passes in proximity of the arc-breaking plates 40 through a channel formed by the aligned grooves 410. Such a solution is particularly useful to favor the commutation of electric arcs towards the arc-breaking plates 40 and the splitting of said electric arcs in arc segments once they have reached the arc-breaking plates.

[0057] The shape of the groove 410 may be designed according to the needs, e.g. rectangular as shown in the cited figures.

[0058] Preferably, the arc-breaking assembly 4 comprises a shaped holder 45 of electrically insulating material, preferably of plastic material (e.g. PTFE, PBT, PMMA, PA6 or another similar material) operatively coupled to the arc-breaking plates 40 to maintain these latter in their stacked position.

[0059] Preferably, the shaped holder 45 has supporting elements 45a operatively coupled to the arc-breaking plates 40 at one or more corresponding sides 401-404 of these latter.

[0060] Preferably, the supporting elements 45a externally delimit, at least partially, the above-mentioned surfaces 400 of the arc-breaking plates 40a, 40b, 40c at one or more sides 401-404 of these latter.

[0061] Preferably, the shaped holder 45 has supporting portions 45b that are fixable to the fixed contact 2 of the corresponding electric pole 10.

[0062] Preferably, the arc-breaking plates 40a, 40b, 40c are electrically disconnected from the electric contacts 2, 3 of the corresponding electric pole 10 and from other live parts of said electric pole. Therefore, they are normally at a floating voltage potential during the operation of the switching apparatus.

[0063] According to other embodiments of the invention, suitable power electronic circuits (which may be designed according to solutions of known type) may be adopted to couple electrically the arc-breaking plates 40 with the corresponding fixed contact 2.

[0064] Preferably, the arc-breaking plates 40a, 40b, 40c are made of a ferromagnetic material, normally a metallic material (e.g. mild steel, cobalt, nickel, iron and the like), which may be optionally coated with an additional material, for example a material (like copper) having an improved electric conductivity.

[0065] According to some embodiments of the invention, however, the the arc-breaking plates 40a, 40b, 40c may include portions of non-ferromagnetic metallic material, e.g. copper, stainless steel, brass, aluminum, and the like.

[0066] Preferably, the switching apparatus 1 is of the gas-insulated type, e.g. a gas-insulated medium-voltage circuit breaker. In this case, the switching apparatus comprises at least an arc chamber (not shown) having an internal volume, in which the one or more fixed contacts 2, one or more movable contacts 3 and one or more arc-breaking assemblies 4 of one or more electric poles are accommodated.

[0067] Preferably, such at least an arc chamber is filled with an insulating gas, for example SF6. However, said arc chamber may be filled with a more environment-friendly insulating gas. For example, it may be used an insulating gas selected in a group including CO2, O2, N2, H2, air, N_2O, a hydrocarbon compound (in particular CH4), a perfluorinated compound, a partially hydrogenated organofluorine compound, or mixture products thereof.

[0068] As another example, it may be used an insulating gas including a background gas selected in a group including CO_2, O_2, N_2, H_2, air, in a mixture with an organofluorine compound selected in a group including fluoroether, oxirane, fluoramine, fluoroketone, fluoroolefin, fluoronitrile, and mixture and/or decomposition products thereof.

[0069] According to the invention, the arc-breaking assembly 4 comprises shielding means 41, 42, 43 made of electrically insulating material, which are operatively coupled to the fixed contact 2 and to the arc-breaking plates 40a, 40b, 40c.

[0070] The shielding means 41, 42, 43 are adapted to cover partially corresponding surfaces 200, 400 of the fixed contact 2 and the arc-breaking plates 40a, 40b, 40c, which are exposed to possible electric arcs, during an opening manoeuvre of the switching apparatus.

[0071] The shielding means 41, 42, 43 reduce the extension of the surfaces 200, 400 exposed to possible electric arcs during an opening manoeuvre of the switching apparatus.

[0072] In this way, when they are generated due to the separation of the electric contacts 2-3, electric arcs follow predictable paths 50a, 50b, 50c between mutually facing conductive surface portions of the fixed contact 2 and of the arc-breaking plates 40a, 40b, 40c, which are not covered by said shielding means.

[0073] The above-mentioned shielding means 41, 42, 43 can be designed in such a way that possible electric arcs arising during an opening manoeuvre of the switching apparatus follow predefined desired paths favouring the arc-quenching process.

[0074] Electric arcs may thus be induced to move away from break-down regions where the insulating gas reaches higher temperatures.

[0075] Additionally, electric arcs may be induced to move along paths having a relatively small section and an increased length in such a way to increase the equivalent resistance seen by the arc currents. As an example, the size of said arc channels (cross section measured on plane parallel to the arc-breaking plates) may be about 5 to 10 mm for nominal line currents about 1 kA.

[0076] Conveniently, the above-mentioned shielding means are formed by shaped inserts 41, 42, 43 of electrically insulating material, which are arranged in such a way to cover partially corresponding exposed surfaces 200, 400 of the fixed contact 2 and of the arc-breaking plates 40a, 40b, 40c.

[0077] Preferably, said electrically insulating material is a plastic material, such as PTFE, PBT, PMMA, PA6 or another similar material.

[0078] The use of inserts of insulating materials to obtain electric arc confinement allows remarkably increasing the ablation process of insulating material during electric arcing, which greatly favours the cooling of hot plasma regions.

[0079] Preferably, the above-mentioned shielding means comprises one or more first inserts 41 of insulating material, which partially surround the fixed contact 2 and are arranged in such a way to cover partially correspond-

ing surfaces 200 of the fixed contact 2.

[0080] When the fixed contact 2 has a single blade, the first inserts 41 are arranged in such a way to cover partially the external surfaces 200 of the contact blade parallel to the trajectory plane of the movable contact 3 during the manoeuvres of the switching apparatus.

[0081] When the fixed contact 2 has multiple blades, the first inserts 41 are also arranged at the gaps between the blades of the fixed contact 2. In this way, they can partially cover the external surfaces and the mutually facing internal surfaces 200 of the contact blades, which are parallel to the trajectory plane of the movable contact 3 during the manoeuvres of the switching apparatus.

[0082] In principle, the first inserts 41 of insulating material may have any shape, which may be designed according to the needs.

[0083] Preferably, the first inserts 41 of insulating material have shaped portions 41a, which are interposed between the fixed contact 2 and the first arc-breaking plate 40a arranged in proximal position with respect to said fixed contact (figures 7-8).

[0084] Preferably, the portions 41a of the first plastic inserts are arranged (e.g. L-shaped) in such a way to cover partially corresponding surfaces 400 of the first arc-breaking plate 40a.

[0085] As it is evident from figures 7-8, the first inserts 41 of insulating material allows driving the electric arcs along a narrow path 50a extending between the fixed contact 2 and the first arc-breaking plate 40a as only small conductive surface portions of the fixed contact 2 (e.g. at the edges of the fixed contact) and of the first arc-breaking plate 40a (e.g. at the center of the arc-breaking plate) are still exposed to electric arcs.

[0086] This solution prevents electric arcs from moving laterally, i.e. along directions perpendicular to the blades forming the fixed contact 2.

[0087] Additionally, electric arcs are driven along paths, which intrinsically have a relatively high electric resistance, thereby favoring the quenching process of the electric arcs.

[0088] Finally, it is enhanced the ablation process of insulating material in the gap between the fixed contact 2 and the first arc-breaking plate 40a, which further improves arc quenching. According to other embodiments of the invention, however, the first inserts 41 of insulating material may be fixed to the fixed contact 2 and, possibly, to the first arc-breaking plate 40a through mechanical means of known type.

[0089] Preferably, the above-mentioned shielding means comprises one or more second inserts 42 of electrically insulating material, which are interposed between adjacent arc-breaking plates 40a, 40b, 40c. The second inserts 42 are arranged in the gaps between adjacent arc-breaking plates 40a, 40b, 40c in such a way to cover partially corresponding mutually facing surfaces 400 of said adjacent arc-breaking plates.

[0090] The second inserts 42 of insulating material allows confining electric arcs along narrow channels 50b extending between conductive surface portions of adjacent arc-breaking plates 40a, 40b, 40c. In this way, possible movements of electric arcs along the surface of the arc-breaking plates can be controlled in a more predictable manner in such a way to prevent arc-bridging phenomena. In addition, electric arcs are in close contact with the insulating material of the inserts 42, which greatly improves ablation of said insulating material and the consequent cooling of electric arcs in the gaps between the arc-breaking plates.

[0091] In principle, the second inserts 42 of insulating material may have any shape, which may be designed according to the needs.

[0092] Figures 3-4, 7-8 show embodiments of the invention, in which the second inserts 42 of insulating material have an arrow-like shape and are arranged in such a way to cover a central portion of a corresponding arc-breaking plate.

[0093] Figure 9 shows an embodiment of the invention, in which the second inserts 42 of insulating material are shaped in such a way to define a single central rectangular portion of conductive surface to be exposed to the electric arcs.

[0094] Additional inserts of this type may be used also to cover the surface 400 of the first arc-breaking plate 40a, which faces the fixed contact 2, when this latter has a single blade.

[0095] Figure 10 shows an embodiment of the invention, in which the second inserts 42 of insulating material are shaped in such a way to define two central rectangular portions of conductive surface to be exposed to the electric arcs.

[0096] Additional inserts of this type may be used also to cover the surface 400 of the first arc-breaking plate 40a, which faces the fixed contact 2, when this latter has two blades.

[0097] The second inserts 42 shown in figures 3-4, 7-10 are particularly suitable for being coupled to arc-breaking plates 40a, 40b, 40c having a substantially rectangular shape (figure 5).

[0098] The second inserts 42 may however be designed in such a way to be particularly adapted for coupling with arc-breaking plates 40a, 40b, 40c of different type, for example T-shaped arc-breaking plates.

[0099] Figure 11 shows an embodiment of the invention, in which the second inserts 42 of insulating material are shaped in such a way to define two lateral spiral-shaped portions of surface 400 to be exposed to the electric arcs.

[0100] Figure 12 shows an embodiment of the invention, in which the second inserts 42 of insulating material are shaped in such a way to define two lateral zigzag-shaped portions of surface 400 to be exposed to the electric arcs.

[0101] According to some embodiments of the invention, the second inserts 42 of insulating material are made in one piece with the plastic holder 45 of the arc-breaking plates.

[0102] According to other embodiments of the invention, the second inserts 42 of insulating material may be fixed to the arc-breaking plates 40a, 40b, 40c through mechanical means of known type. Preferably, the above-mentioned shielding means comprises one or more third inserts 43 of electrically insulating material, which are arranged to cover partially corresponding surfaces 400 of the last arc-breaking plate 40c in distal position with respect to said fixed contact 2. Conveniently, the third inserts 43 of insulating material partially cover corresponding surfaces 400 of the last arc-breaking plate, which are facing the exterior of the arc-breaking assembly in an opposite direction with respect to the fixed contact 2.

[0103] In this way, possible electric arcs may be confined in relatively long narrow channels 50c extending between the last arc-breaking plate 40c and the movable contact 3, thereby preventing said electric arcs from moving away towards other portions of the arc-chamber.

[0104] In principle, the third inserts 43 of insulating material may have any shape, which may be designed according to the needs, for example as illustrated above for the second inserts 42 of insulating material

[0105] Preferably, the third inserts 43 of insulating material are made in one piece with the plastic holder 45 of the arc-breaking plates. According to other embodiments of the invention, the third inserts 43 of insulating material may be fixed to the last arc-breaking plate 40c through mechanical means of known type.

[0106] Figures 13-14 show pictures showing the results of tests carried out on different types of arc-breaking plates 40a, 40b, 40c.

[0107] Figure 13 shows some test results concerning arc-breaking plates 40a, 40b, 40c (of the type shown in figure 5), which have been coupled to second inserts 42, 43 of insulating material having an arrow-like shape (figures 2-4, 7-8), during subsequent opening manoeuvres of the switching apparatus.

[0108] Figure 14 shows some test results concerning arc-breaking plates 40a, 40b, 40c (of the type shown in figure 6), which have been coupled to second inserts 42, 43 of insulating material having a spiral shape (figure 11), during subsequent opening manoeuvres of the switching apparatus.

[0109] In both the above-mentioned pieces of evidence, the foot-prints of the electric arcs affecting the arc-breaking plates during the opening manoeuvres are clearly visible. It is apparent how electric arcs did not affect surface portions covered by the corresponding inserts 42, 43 of insulating material. Electric arcs were instead confined along paths between the conductive surface regions not covered by the corresponding inserts 42, 43 of insulating material and still exposed to electric arcs.

[0110] The switching apparatus 1, according to the invention, provides relevant advantages with respect to corresponding known switching systems of the state of the art.

[0111] The switching apparatus 1 includes, for each electric pole, an arc-breaking assembly 4 having improved current quenching capabilities.

[0112] According to the invention, the arc-breaking assembly 4 includes shielding means 41, 42, 43 of electrically insulating material operatively coupled to the fixed contact 2 and to the arc-breaking plates 40a, 40b, 40c.

[0113] As illustrated above, the above-mentioned shielding means make electric arcs to be confined along predictable paths, during the opening manoeuvres of the switching apparatus. This allows remarkably improving the quenching process of the electric arcs.

[0114] Additionally, the above-mentioned shielding means provide a remarkable increase of the quantity of insulating material ablated during arcing phenomena, which greatly contributes to cool down hot regions of insulating gas.

[0115] The above-mentioned shielding means may be easily manufactured at industrial level, e.g. through suitable moulding processes. Conveniently, the above-mentioned shielding means may be integrated with the plastic holder 45 of the arc-breaking plates and realized, at least partially, in one piece with this latter.

[0116] The switching apparatus 1 is relatively easy and cheap to manufacture at industrial level with well-established manufacturing techniques. It may therefore be manufactured at competitive costs with similar switching systems of the state of the art.

[0117] The switching apparatus 1 is particularly adapted for use in AC medium-voltage applications.

[0118] However, it may be conveniently designed for use in applications of different type, such as in DC applications or in low-voltage applications.

Claims

1. A switching apparatus (1) for electric power distribution grids comprising:

   - one or more electric poles (10);
   - for each electric pole, at least a fixed contact (2) and a movable contact (3), said movable contact being reversibly movable between a coupled position, at which said movable contact is coupled to said fixed contact, and an uncoupled position, at which said movable contact is separated from said fixed contact;
   - for each electric pole, an arc-breaking assembly (4) comprising a plurality of arc-breaking plates (40a, 40b, 40c) arranged side by side and spaced one from another; **characterised in that** said arc-breaking assembly (4) comprises shielding means (41, 42, 43) of electrically insulating material operatively coupled to said fixed contact (2) and to said arc-breaking plates (40a, 40b, 40c), said shielding means partially covering surfaces (200, 400) of said fixed contact and

said arc-breaking plates, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

2. Switching apparatus, according to claim 1, **characterised in that** said shielding means are configured in such a way to confine possible electric arcs, during an opening manoeuvre of said switching apparatus, at predefined paths (50a, 50b, 50c) extending between mutually facing surface portions of said fixed contact (2) and of said arc-breaking plates (40a, 40b, 40c), which are not covered by said shielding means.

3. Switching apparatus, according to one or more of the previous claims, **characterised in that** said shielding means comprise one or more shaped inserts (41, 42, 43) of electrically insulating material, said inserts partially covering corresponding surfaces (200, 400) of said fixed contact and said arc-breaking plates, which are exposed to possible electric arcs, during an opening manoeuvre of said switching apparatus.

4. Switching apparatus, according to claim 3, **characterised in that** said shielding means comprise one or more first inserts (41) of electrically insulating material, said first inserts surrounding at least partially said fixed contact (2) and partially covering corresponding surfaces (200) of said fixed contact.

5. Switching apparatus, according to claim 4, **characterised in that** one or more of said first inserts (41) have shaped portions (41a), which are interposed between said fixed contact (2) and a first arc-breaking plate (40a) in proximal position with respect to said fixed contact (2), said shaped portions partially covering corresponding surfaces (400) of said first arc-breaking plate.

6. Switching apparatus, according to one of the claims from 3 to 5, **characterised in that** said shielding means comprises one or more second inserts (42) of electrically insulating material, said second inserts being interposed between adjacent arc-breaking plates (40a, 40b, 40c) and partially covering corresponding mutually facing surfaces (400) of said adjacent arc-breaking plates.

7. Switching apparatus, according to one of the claims from 3 to 6, **characterised in that** said shielding means comprises one or more third inserts (43) made of electrically insulating material, said third inserts partially covering corresponding surfaces (400) of a last arc-breaking plate (40c) in distal position with respect to said fixed contact (2).

8. Switching apparatus, according to one or more of the previous claims, **characterised in that** said arc-breaking assembly (4) comprises a shaped holder (45) of electrically insulating material.

9. A switching apparatus, according to one or more of the previous claims, **characterised in that** it comprises at least an arc chamber including one or more fixed contacts (2), one or more movable contacts (3) and one or more arc-breaking assemblies (4), said arc chamber being filled with an insulating gas.

10. A switching apparatus, according to one or more of the previous claims, **characterised in that** it is a medium-voltage circuit breaker.

11. A medium-voltage electric system comprising a switching apparatus (1), according to one or more of the previous claims.

FIG. 1

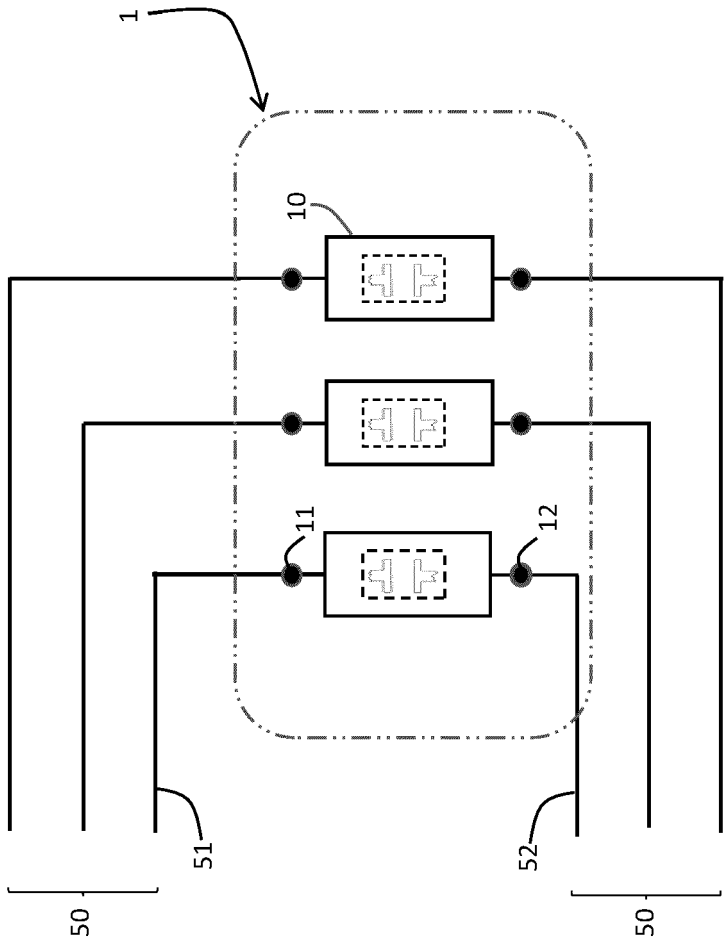


FIG. 2

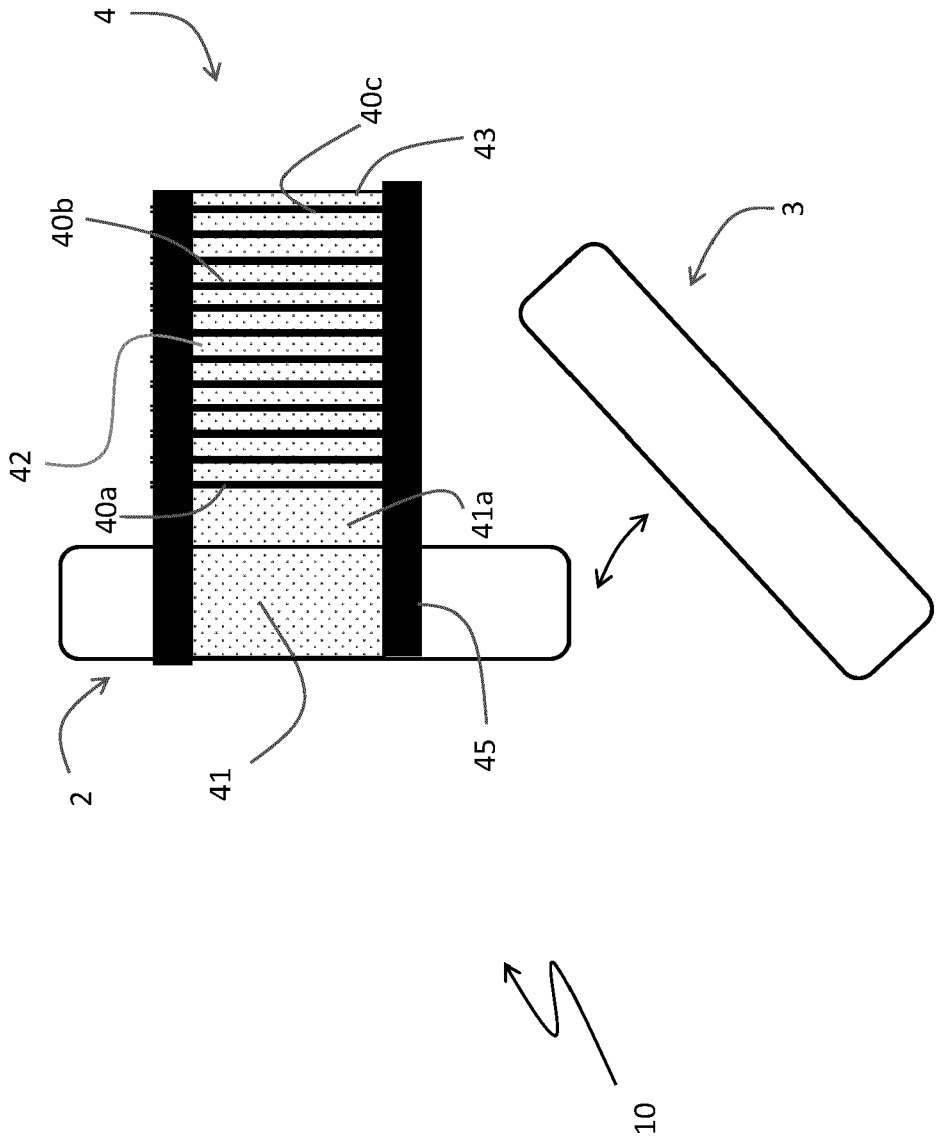


FIG. 3

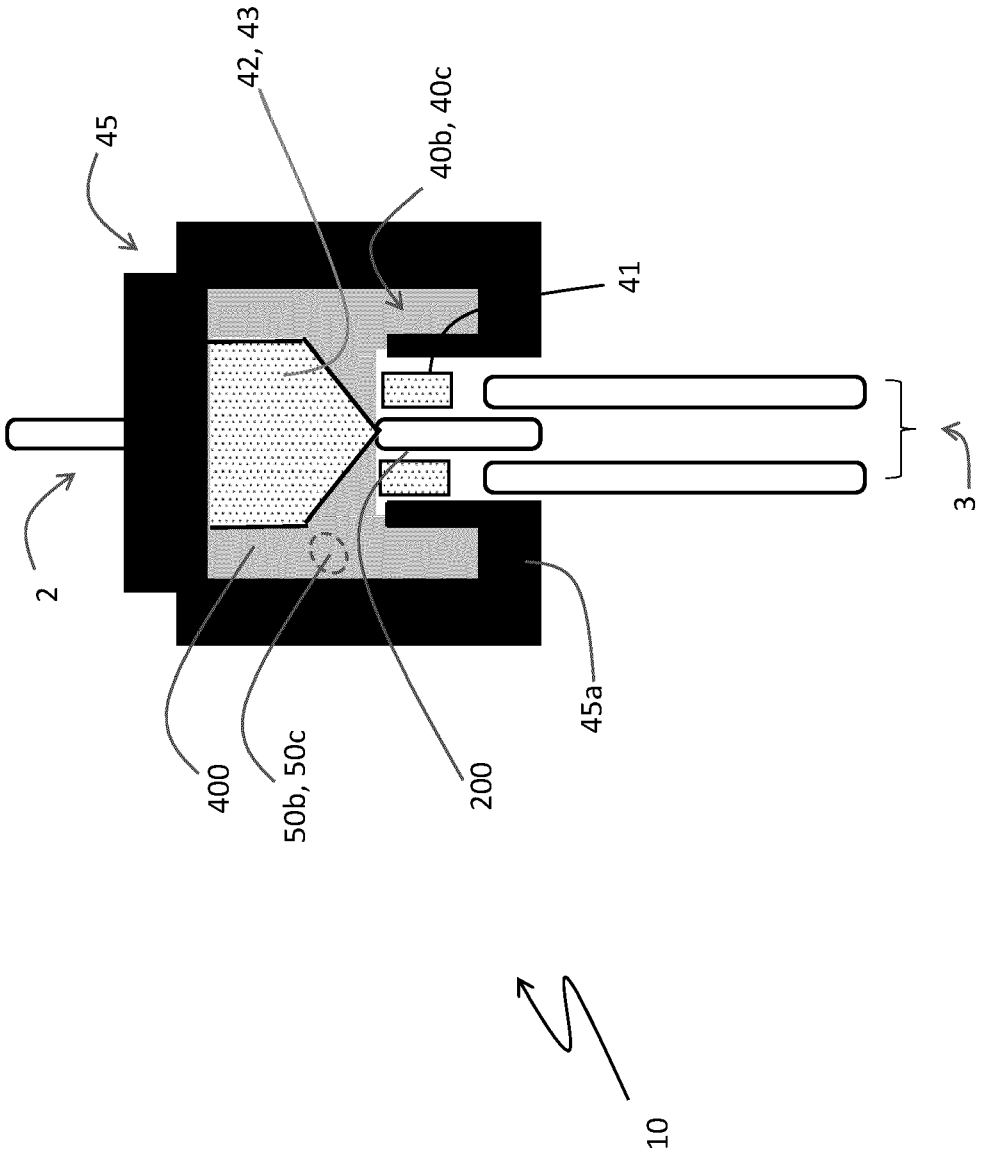


FIG. 4

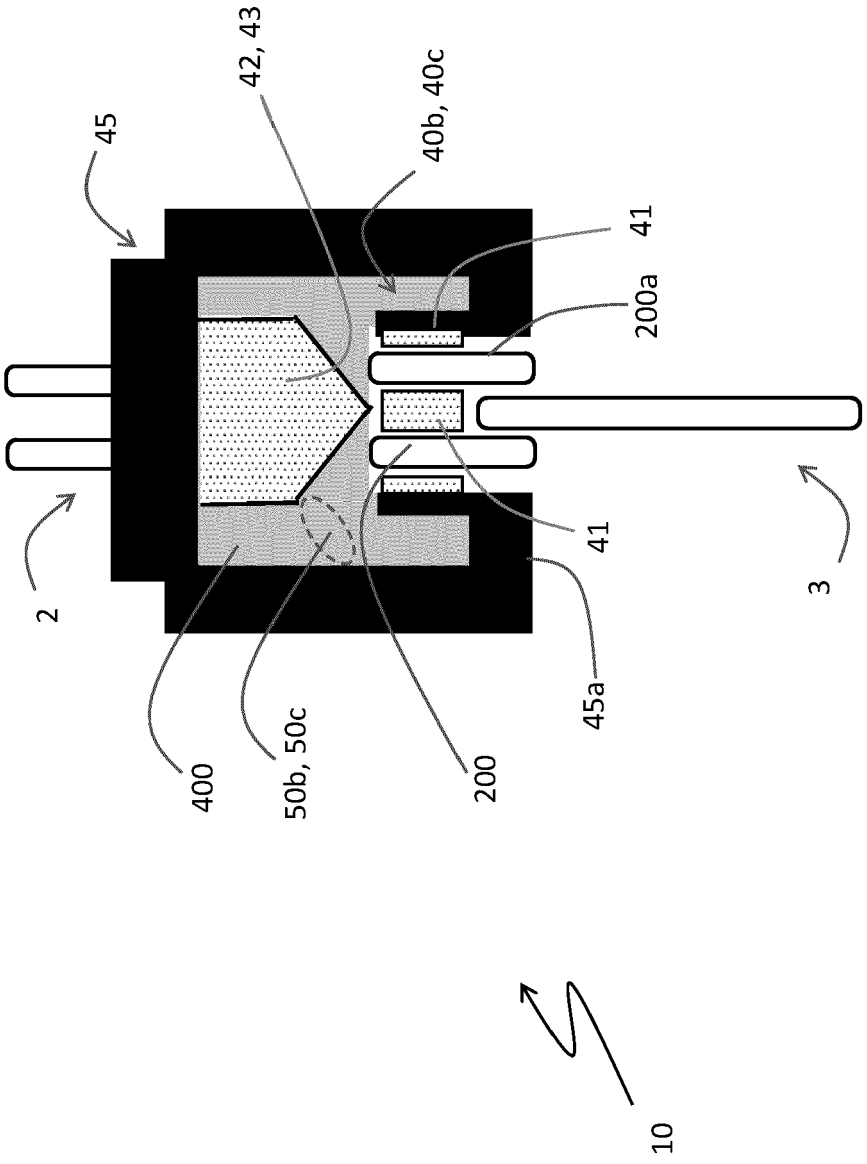


FIG. 5

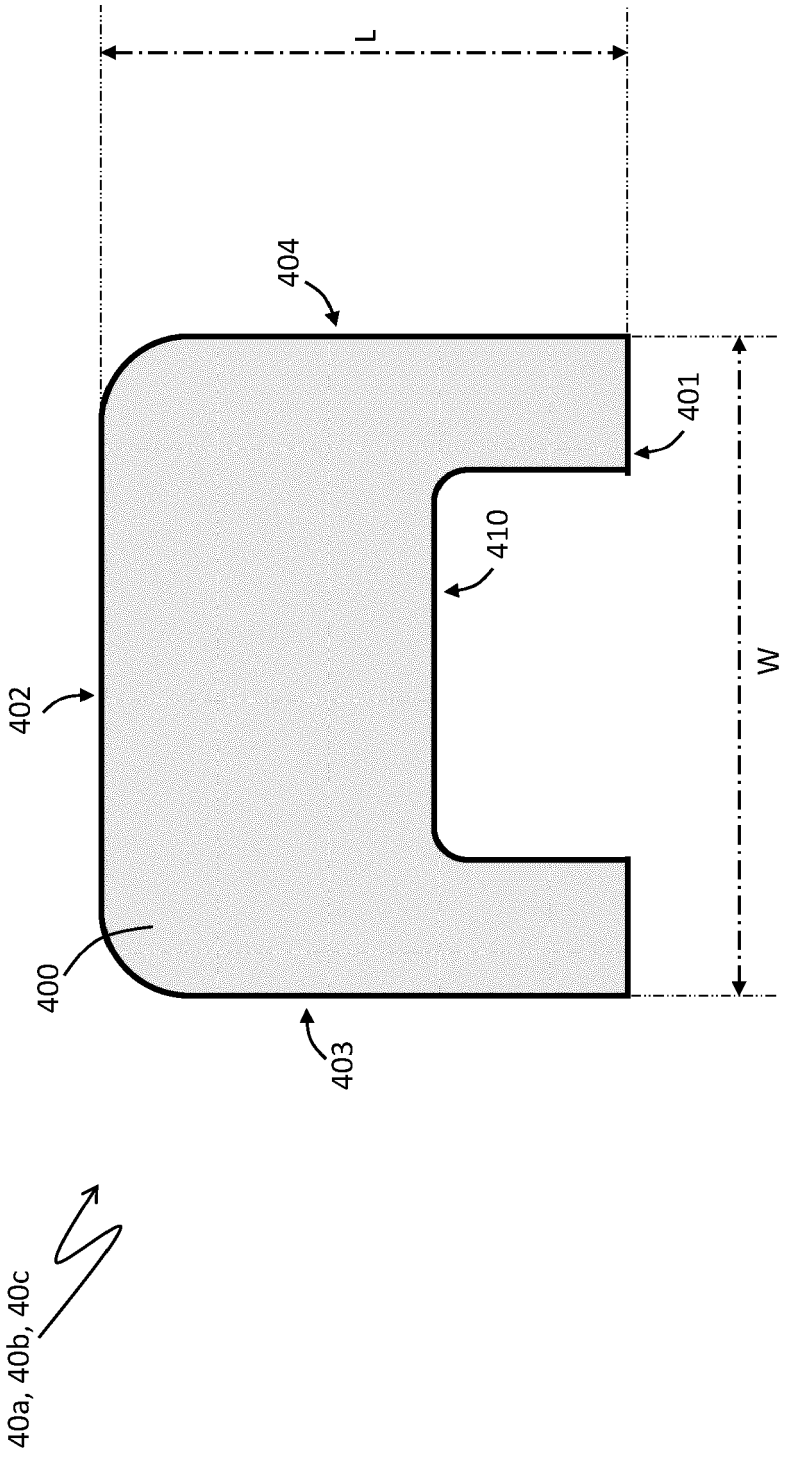


FIG. 6

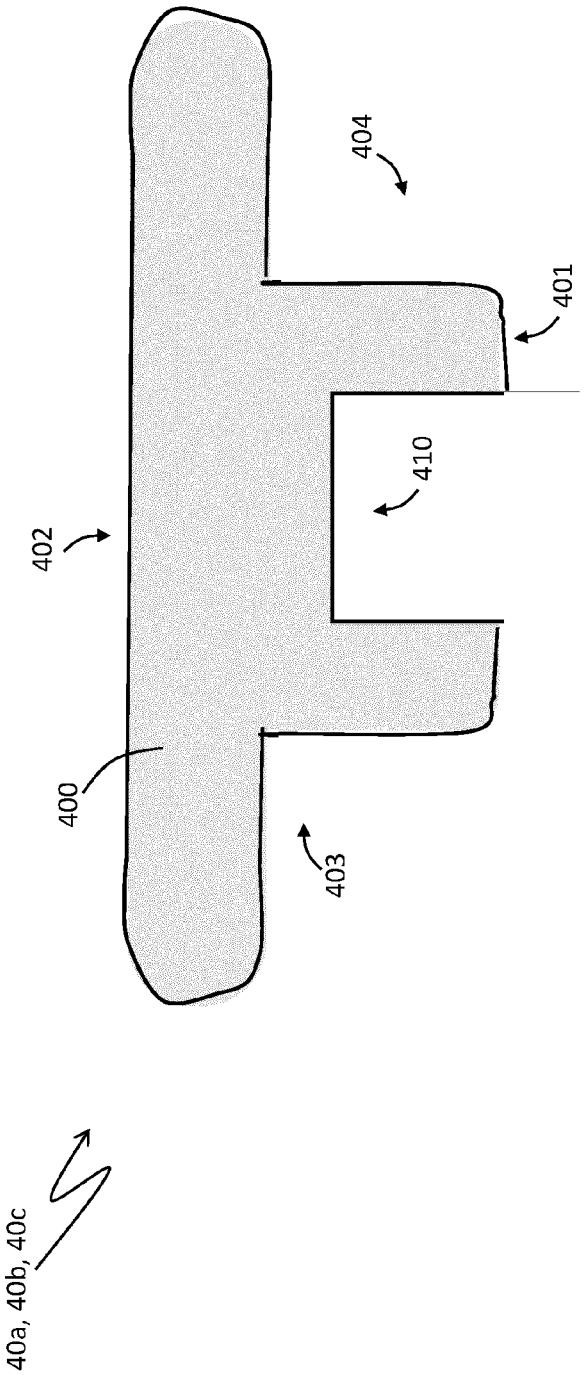


FIG. 7

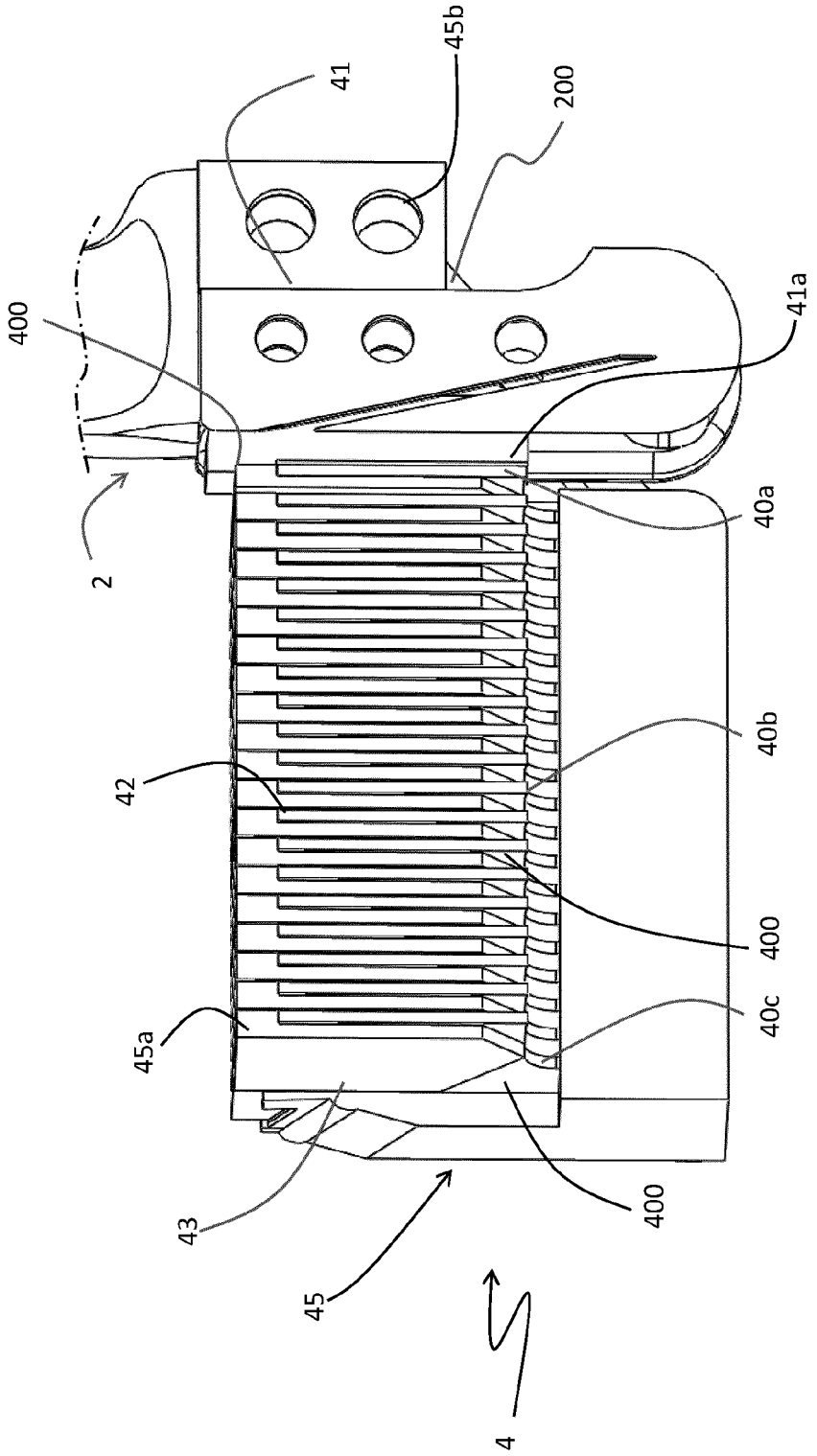


FIG. 8

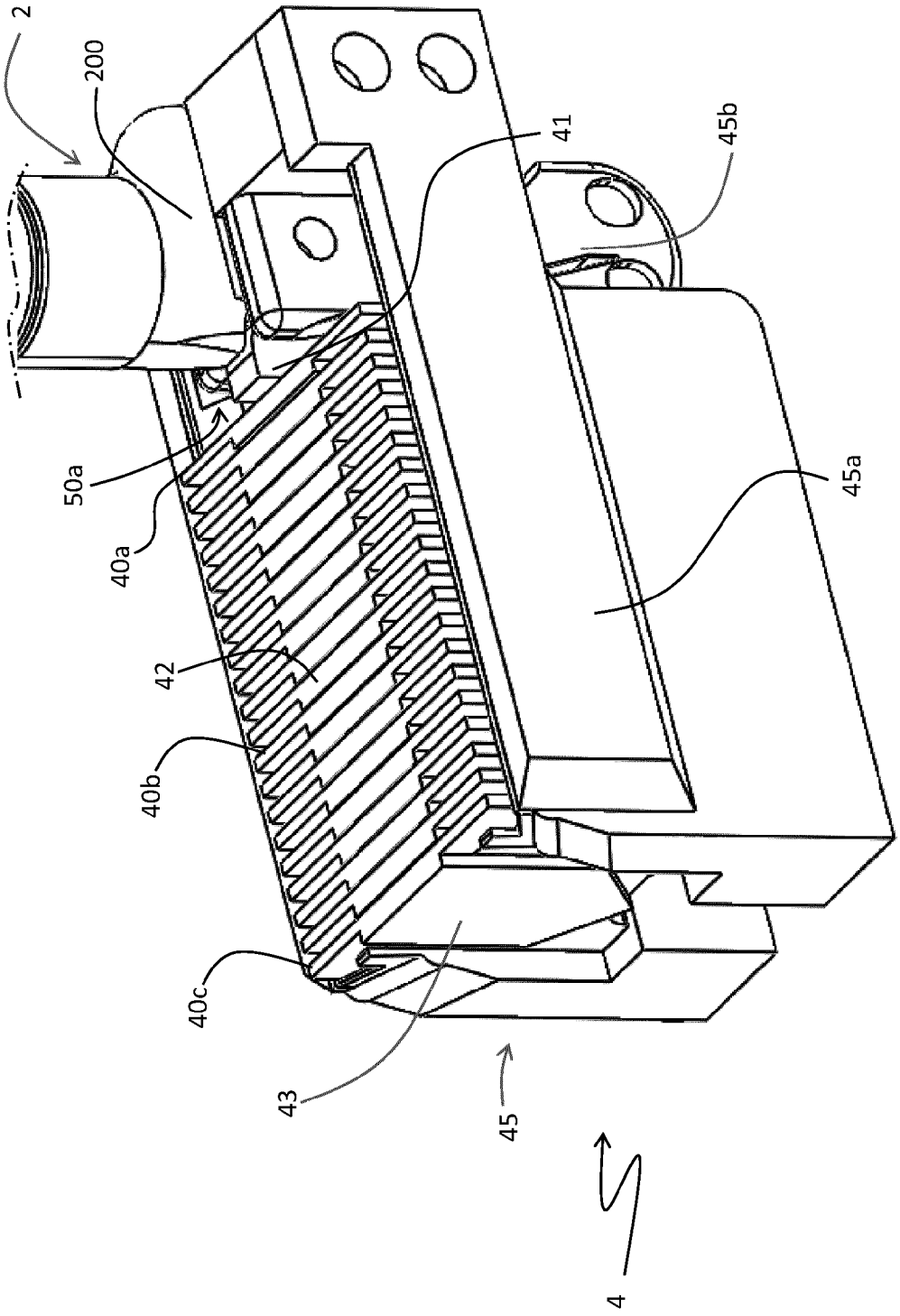


FIG. 9

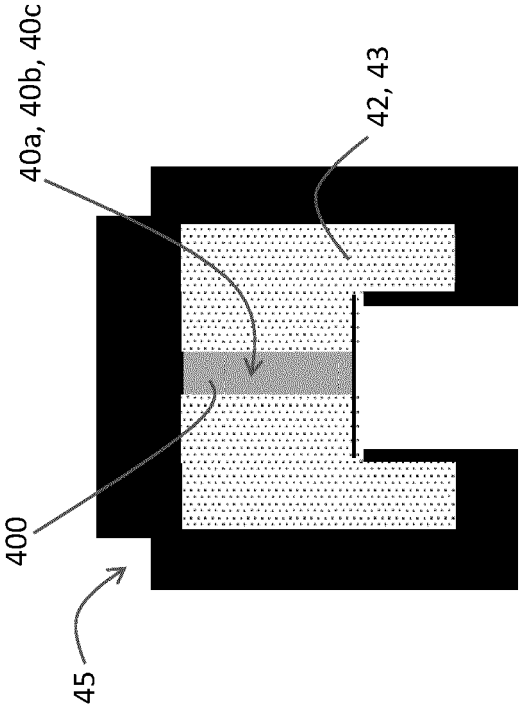


FIG. 10

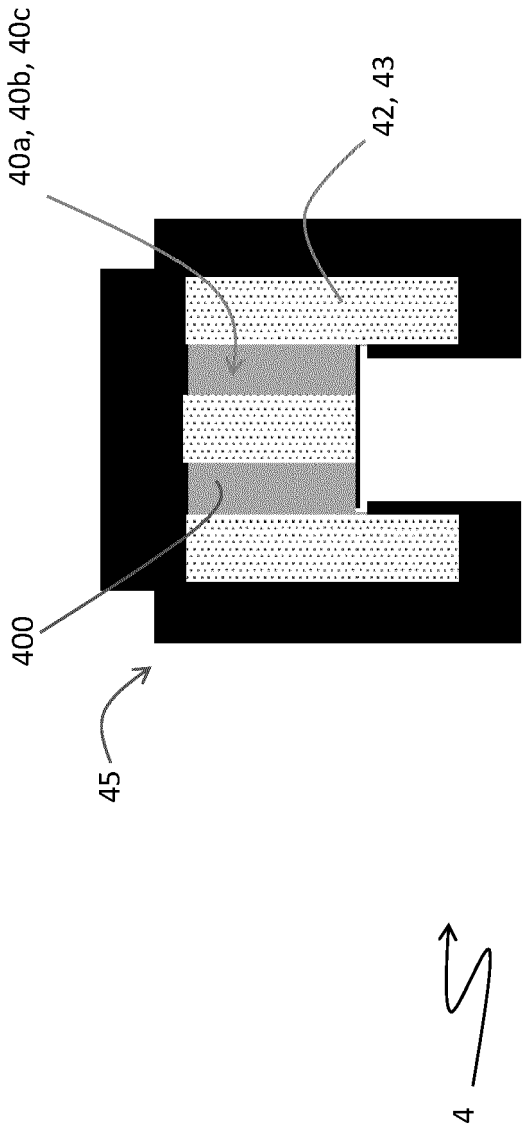


FIG. 11

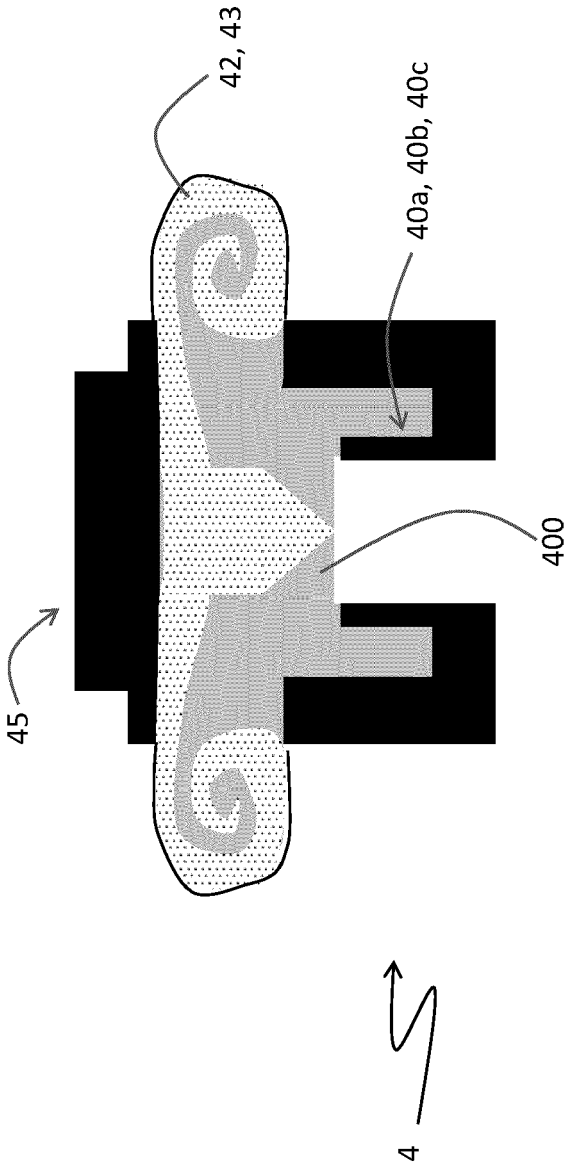


FIG. 12

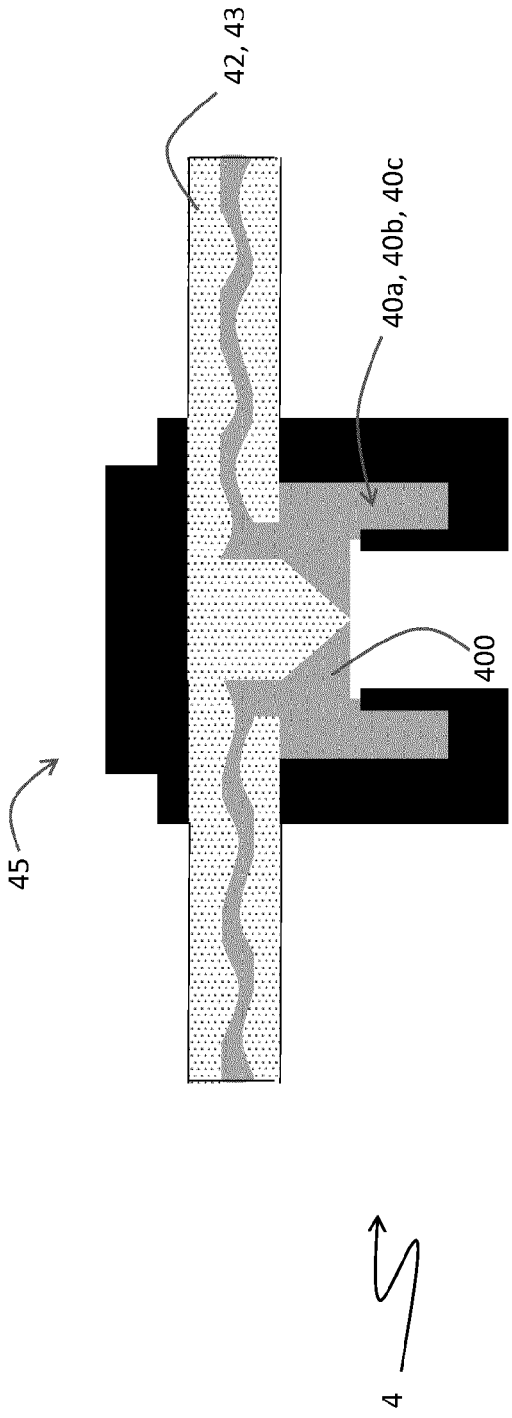
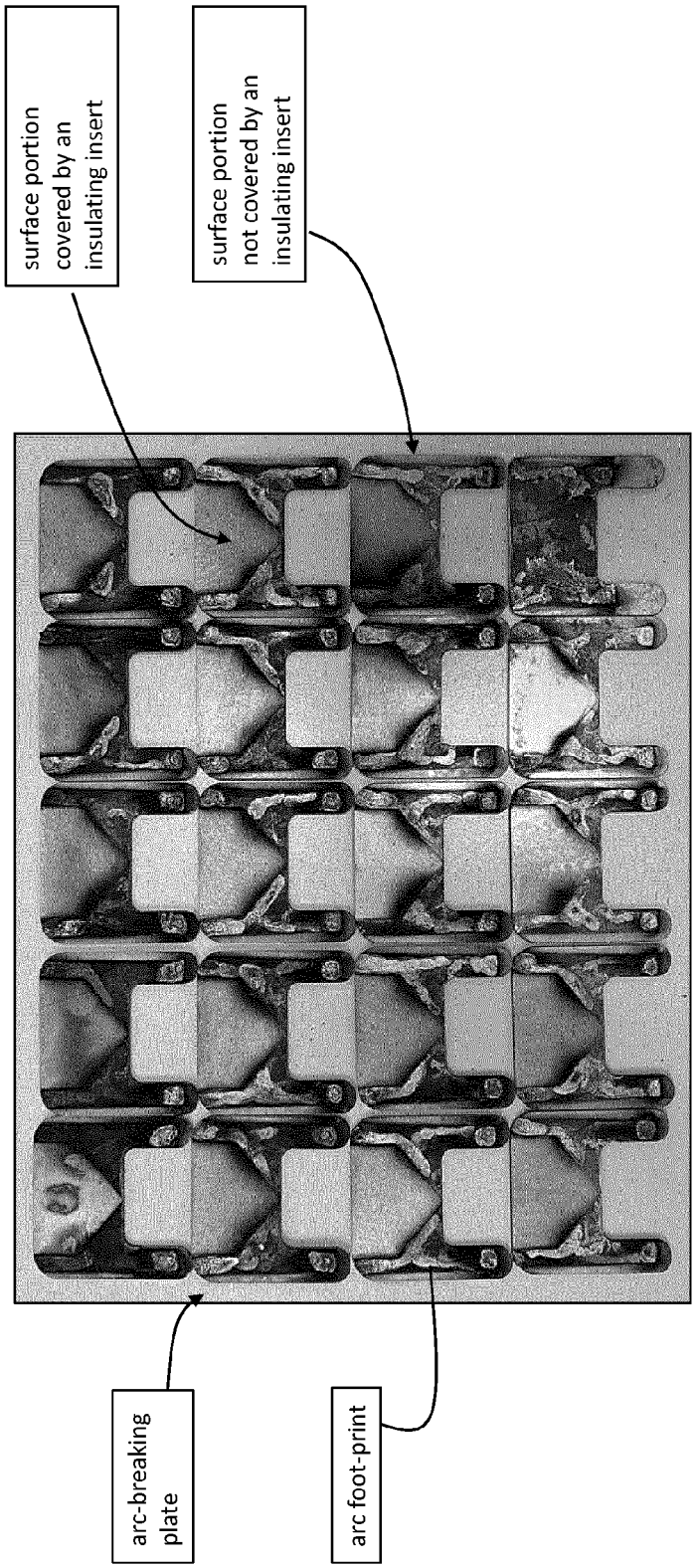


FIG. 13


surface portion covered by an insulating insert
surface portion not covered by an insulating insert
arc-breaking plate
arc foot-print

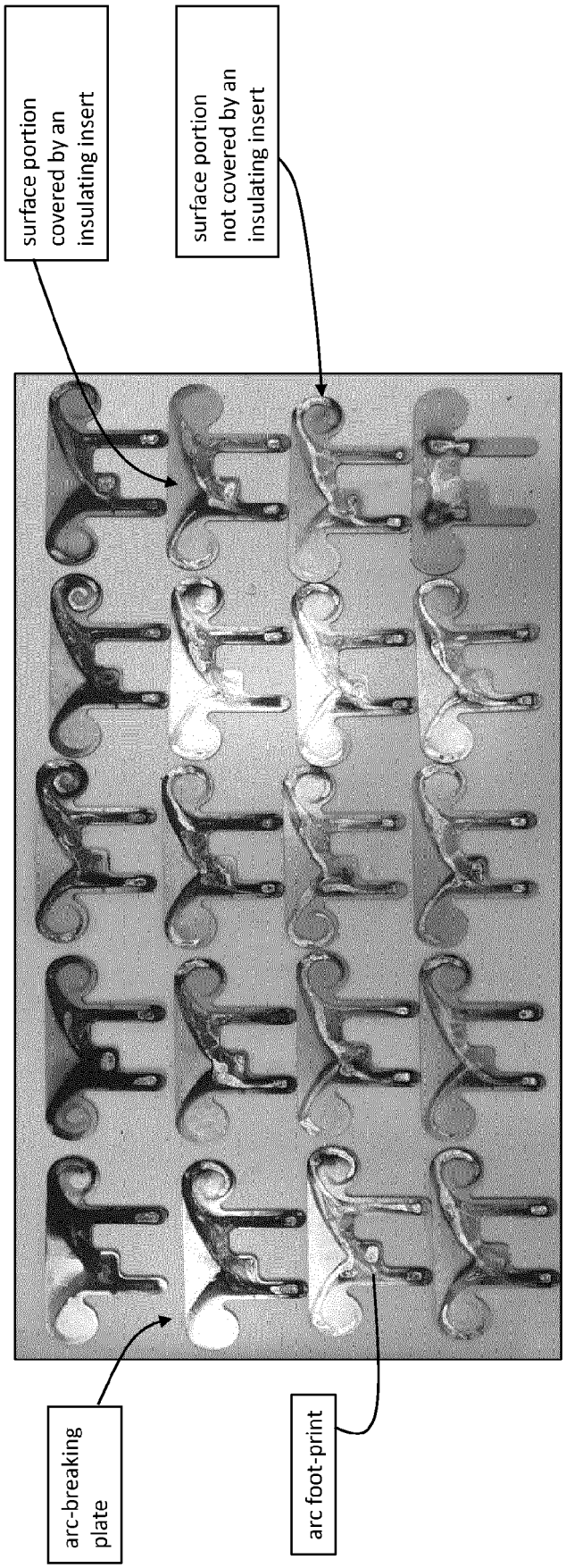

surface portion covered by an insulating insert
surface portion not covered by an insulating insert
arc-breaking plate
arc foot-print

FIG. 14

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EUROPEAN SEARCH REPORT

Application Number
EP 20 18 3497

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	25 November 2020	Ernst, Uwe

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