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• **Seeger, Martin**
CH-5600, Ammerswil (CH)
• **Manz, Erwin**
79787, Lauchringen (DE)

(74) Representative: **ABB Patent Attorneys**
C/o ABB Schweiz AG
Intellectual Property (CH-LC/IP)
Brown Boveri Strasse 6
5400 Baden (CH)

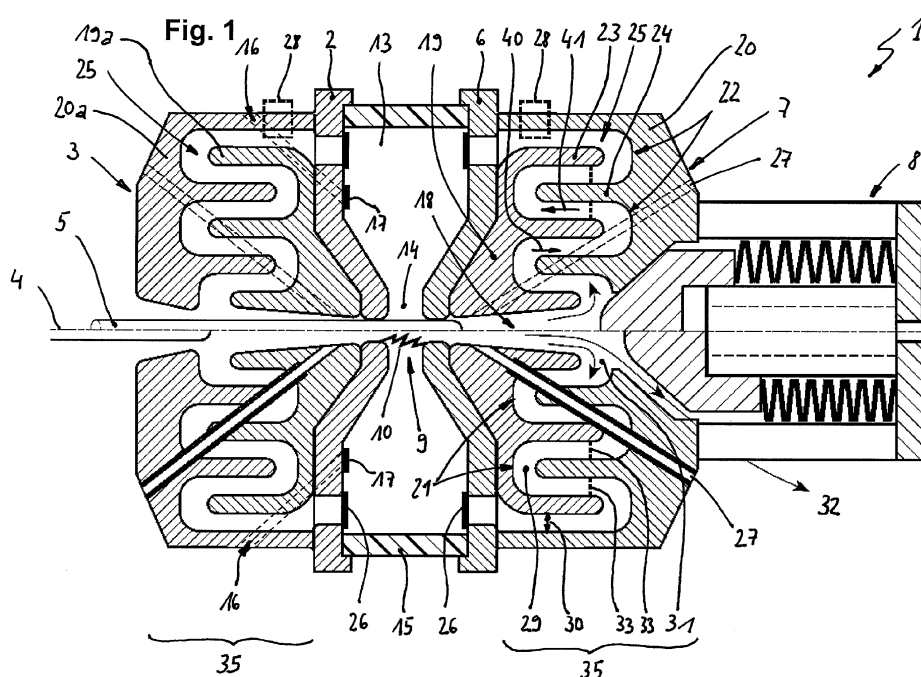
(71) Applicant: **ABB Research Ltd.**
8050 Zürich (CH)

(72) Inventors:
• **Basse, Nils**
8906, Bonstetten (CH)

(54) **Gas insulated circuit breaker**

(57) A circuit breaking method of a gas-blown circuit breaker (1) comprising an interruption chamber with an arcing zone. An amount of insulating gas is stored and pre-compressed in a second heating volume (25) of the interruption chamber. The second heating volume is fluidly connected with the arcing zone and the first heating volume (13) that is fluidly connected with the arcing zone (9), too. After arc generation the amount of insulating gas

in the second heating volume is pressurized by heated insulating gas entering the second heating volume from the arcing zone. The heated insulating gas entering the second heating volume from the arcing zone is guided by a gas guiding means (23) of the second heating volume such that it is suppressed from mixing with the stored amount of insulating gas in the second heating volume by a gas guiding means of the second heating volume.



Description

TECHNICAL FIELD

[0001] The invention relates to a gas insulated circuit-breaker such as those used in power plants, transformer substations and other installations in the supply of electric energy for connecting and disconnecting operating currents and overcurrents as well as to an arc interruption method according to the preamble of the independent claims.

BACKGROUND OF THE INVENTION

[0002] The gas flow that is necessary for arc extinction requires a comparatively large difference in gas pressure which is generated by the electric arc itself. The concept of employing the pinch pressure produced during the formation of an electric arc in between two electrical contacts at high currents for extinguishing the electric arc with a strong gas flow resulting of said pinch pressure is known from US6163001A1 or EP1225610B1 for example. In these circuit breakers, the required pressure build-up in the heating volumes is supplied by the pinch pressure of the electric arc. That pinch pressure is produced by a rapid contraction of the same in the region of the switching axis and causes during a very limited amount of time a strong axial gas that flows from the arcing chamber or zone into the pinch pressure chamber and an intense pressure rise in the latter. Hence a strong axial pressure gradient is produced, which pressure is partly diverted into the heating volumes via a return channel.

[0003] If short circuit currents higher than about 150 kA in a 60 Hz network at about 30 kV are to be interrupted with the above-mentioned circuit breakers, the rated voltage needs to be decreased in order to ensure a proper interruption operation due to the high temperatures of the gas flow extinguishing the arc at such high short circuit currents.

BRIEF SUMMARY OF THE INVENTION

[0004] It is therefore an object of the present invention to further develop the prior art devices and to provide both a circuit interruption method and a suitable circuit breaker that allow for interrupting maximal currents being higher than about 150kA, without the need of reducing the rated voltage to such an extent as indicated above.

[0005] These objects are achieved by the features according to the independent claims. Particular embodiments thereof are claimed by dependent claims.

[0006] With respect to the inventive circuit interruption method, the object is solved by the following steps:

a) Providing a gas-blown circuit breaker having an interruption chamber filled with an insulating gas, said interruption chamber comprising an arcing zone and at least two separable arcing contacts;

b) Storing an amount of insulating gas in a second heating volume of the interruption chamber, said second heating volume being fluidly connected with the arcing zone and fluidly connectable with a first heating volume, wherein said first heating volume is fluidly connected with the arcing zone;

c) Separating the arcing contacts from one another such that an electric arc is generated between said arcing contacts and such that a gas pressure caused by the electric arc in the second heating volume is higher than about 3 bar relative to a nominal gas pressure;

d) Pressurizing the amount of insulating gas in the second heating volume by heated insulating gas entering the second heating volume from the arcing zone;

e) Guiding at least the heated insulating gas entering the second heating volume from the arcing zone at least during step d) such that the heated insulating gas entering the second heating volume from the arcing zone is suppressed from mixing with the stored amount of insulating gas in the second heating volume by a gas guiding means of the second heating volume, wherein the second heating volume is at least 20% as large as the first heating volume;

f) Injecting the amount of insulating gas stored in the second heating volume into the first heating volume by a gas pressure applied on the gas stored in the second heating volume by the heated insulated gas from the arcing zone into the first heating volume;

g) Interrupting the electric arc by leading the insulating gas from the first heating volume back into the arcing zone through at least one blow channel.

[0007] The term 'suppressing from mixing' is not to be misunderstood in a way that no gas mixing between heated gas entering the second heating volume, in particular at pinch mode/pinch pressure and the comparatively cold gas stored in the second heating volume prior to the interruption process occurs at all. In fact the term 'suppressing from mixing' should be understood such that the guiding means hinders (i.e. impedes, inhibits or obstructs) the heated gas from mixing with the cold stored gas in the second heating volume substantially such that the cooling effect at the time where the stored cold gas is injected into the first heating volume is achievable. Said in other words, the comparatively small amount of mixed and thus preheated gas at the border of the heated gas and the cold stored gas is insignificant compared to the amount of pressurized cold gas. In this context, the term 'cold' referring to the cold stored gas in the second heating volume shall be understood to be of such value that an average gas temperature of the insulating gas within

the first heating volume prior to the step of interrupting the electric arc is below 2000 Kelvin for avoiding dielectric problems of the blow gas leaving the first heating volume for interrupting the electric arc.

[0008] The term 3 bar relative to a nominal gas pressure is understood as a pressure difference of at least three bars in the interruption zone compared to a nominal gas pressure in the interruption zone prior to arcing and/or after completing initial gas filling at the time of putting the gas-blown circuit breaker into operation.

[0009] In short, the present invention relies on a cold compression, i.e. a pressurization of stored cold gas by employing the pinch effect in which the energy output of the arc, in particular the pinch pressure, is utilized as effectively as possible for blowing out the arc. Although the pinch effect may be useful for supporting the interruption process at currents below 50kA it is of major value if electric arcs originating from currents higher than about 150 kA in particular, e.g. maximal currents being higher than about 150kA, are to be interrupted, with the result that a quick interruption of the circuit is ensured even in the case of high switching capacities and without mechanical blowout devices of large dimension which require high power of the switching drive themselves. Said in other words, a pressurization of the cold gas in the second heating volume becomes particularly powerful if the pinch pressure from the arcing zone originates from currents much higher than 150 kA.

[0010] The following advantages arise of the fact that the second heating volume has a substantial size compared to the first heating volume:

- The second heating volume forms together with the first heating volume an essential space for back-heating, wherein the second heating volume has a cross-section that is substantially larger than that of the feedback loops in the circuit breakers disclosed in US6163001A1 or EP1225610B1.

[0011] At pinch mode conditions originating from electric arcs at currents much higher than 50 kA the back-heating occurs mainly in the second heating volume. Owing to the backheating in the second heating volume at pinch mode a so-called cold compression of the blow gas is achievable which forms a fair part of the blow gas pressure in the first heating volume that is required for effectively interrupting the electric arc at pinch mode conditions. Gas temperatures of the stored and pressurized cold gas below a 1000 Kelvin are achievable prior to the step of injection depending on the embodiment of the circuit breaker.

- Moreover said cold compression provides for blow gas temperatures that are significantly lower than in feedback loop solutions such as proposed by US6163001A1 or EP1225610B1 for example. In any case the blow gas temperature of the blow gas in the first heating volume is lowered prior to an arc

interruption step. Depending on the embodiment of the circuit breaker the blow gas temperature can be kept well below 2000 Kelvin, for example at about or below 1500 Kelvin, such that the dielectric properties of the blow gas can be kept within reasonable limits.

- The size of the second heating volume contributes essentially to an overall gas space such that a metal vapor concentration is lowered compared to feedback loop solutions such as proposed by US6163001A1 or EP1225610B1 for example. The lower a metal vapor concentration in the blow gas is the better the arc interruption properties are. Depending on the actual embodiment of the circuit breaker the cold compression of the stored gas in the second heating volume a compression factor of about 2 to 8 in the second heating volume is achievable prior to the step of injection.

- Owing to the size of the second heating volume the interior surface of the second heating volume is larger than in feedback loop solutions such as proposed by US6163001A1 or EP1225610B1 for example, leading to an increased possibility of condensation of metal vapor. Again, the lower a metal vapor concentration in the blow gas is the better the arc interruption properties are.

- The second heating volume forms a separate heating volume for interrupting currents that are higher than about 150kA, whereas the first heating volume alone is used to interrupting currents that are lower, i.e. below currents lower than 50kA.

[0012] The following advantages arise of the presence of a guiding means in the second heating volume:

- In circuit breakers that comprise feedback loops such as proposed by US6163001A1 or EP1225610B1 the mixing of cold stored gas with heated gas entering the second heating volume from the arcing zone is not detrimental for its function since the cross-section of the feedback channel is small compared to a cross-section of the first heating volume. If the cross-section of the feedback channel is substantially increased for forming a substantial second heating volume, the stored cold gas and the heated gas tend to mix thoroughly such that no cold compression effect is achievable. The tendency to mixing originates from asymmetries of the electric arc during its formation prior to the high-current phase, for example, which asymmetries may lead to asymmetric movements of the gas flow within the second heating volume that lead in term to a cross-mixing of cold and hot insulating gas. In accordance with the present invention the second heating volume comprises guiding means for guiding the heated insulating gas entering the second heating volume

from the arcing zone at least during step d) such that the heated insulating gas entering the second heating volume from the arcing zone is suppressed from mixing with the stored amount of insulating gas in the second heating volume by a gas guiding means of the second heating volume, and such that that a proper (i.e. most direct) gas flow of the cold stored gas into the first heating volume is achievable during the step of injection.

■ Moreover the surface of the guiding means further increases the interior surface of the second heating volume such that it contributes to the condensation of metal vapor on the interior surface of the second heating volume, the lower a metal vapor concentration in the blow gas is, the better the arc interruption properties are.

■ In addition an increased interior surface of the second heating volume owing to the guiding means further allows cooling the insulating gas stored and flowing in it by thermal conduction. The lower the gas temperature of the stored cold gas is, the more it can lower the temperature of the blow gas and thus the better the interruption properties will be.

[0013] If the second heating volume is at least 20 % as large as the first heating volume, the amount of stored cold gas will cause a significant drop in the gas temperature of the blow gas and thus contribute essentially to an excellent interruption quality. In addition or as an alternative, this holds particularly true for interrupting electric arcs being in the pinch mode resulting of currents higher than about 50kA.

[0014] Depending on the requirements on the circuit breaker and the space available for it, in particular for the second heating volume, the guiding means comprises a first guiding element for guiding heated insulating gas entering the second heating volume from the arcing zone in a first direction, and a second guiding element for guiding insulating gas leaving the first portion with the first guiding element in a second direction, wherein the first direction and the second direction have opposite direction components, in particular with respect to a longitudinal direction of the circuit breaker. In such cases it is further advantageous if the longitudinal direction extends along a switching axis such that the energy of the pinch-pressure propagating in an axial direction too is allowed to exert its power at best. This holds particularly true for interrupting electric arcs being in the pinch mode resulting of currents higher than about 50kA. The gas flow in the second heating volume is redirected from the first guiding element to the second guiding element by at least one deflector means, e.g. a bend or the like.

[0015] In addition or as an alternative the guiding means subdivides the second heating volume in a plurality of gas channels that are fluidly disconnected from one another for preventing the heated gas from mixing

with the cold stored gas excessively. Expressed differently, the guiding means may have a labyrinth shape or appearance wherein the guiding means prevent heated gas from flowing straight, i.e. unimpeded from the inlet to second heating volume to the check valve in a radial direction in an example of a cylindrical circuit breaker device. If the guiding means features a divider structure, the divider prevents heated gas from flowing in a circumferential direction with respect to the switching axis and thus from unintended excessive mixing with cold gas.

[0016] The interrupting performance of the blow gas leaving the first heating volume can be further increased if at least one of the cold gases stored in the second heating volume and the gas entering the second heating volume from the arcing zone is actively cooled. Depending on the embodiment of the circuit breaker the active cooling may be performed by at least one cooling element, in particular at least one of a cooling fin and a heat exchanger, for actively cooling at least one of the insulating gas stored in the second heating volume prior to the circuit interruption process and the heated insulating gas entering the second heating volume from the arcing zone. This holds particularly true for interrupting electric arcs being in the pinch mode resulting of currents higher than about 50kA at pinch mode.

[0017] With respect to the inventive circuit breaker, the object is solved by a circuit breaker having the following features: An interruption chamber filled with an insulating gas, at least two separable arcing contacts defining an arcing zone in which an electric arc is producible in between the at least two separable arcing contacts during a circuit interruption process. Further, the interruption chamber comprises a first heating volume that is fluidly connected with the arcing zone and a second heating volume that is fluidly connected with the arcing zone. Said second heating volume is fluidly connectable with the first heating volume via a check valve that opens (depending on the embodiment and requirements) if a gas pressure in the second heating volume exceeds a predefined value, for example if the gas pressure in the second heating volume exceeds a gas pressure in the first heating volume. This holds particularly true for interrupting electric arcs being in the pinch mode resulting of currents higher than about 50kA at pinch mode.

[0018] The second heating volume is at least 20% as large as the first heating volume and comprises a guiding means for guiding at least the heated insulating gas entering the second heating volume from the arcing zone such that the heated insulating gas entering the second heating volume from the arcing zone is suppressed from mixing with an amount of insulating gas stored in the second heating volume prior to the circuit interruption process.

[0019] In particular embodiments of the circuit breaker the second heating volume forms a flow path that has a meander or labyrinth-like appearance. Thus an overall length of the gas flow path formed by the second heating volume may be increased even if there is a comparatively

little longitudinal section (space) of the circuit breaker available. The longer a length of a gas flow path formed by the second heating volume is, the more time and area is available for cooling the heated gas in the second heating volume such that a reduction of metal vapor is further decreasable by condensation on the walls or reaction of the metal vapor to metal-fluorides, where applicable. The term 'meander' is understood to be a maze-like structure having a complex branching (multicursal) puzzle with choices of path and direction. Hence the paths may start, stop, split into two or more parts, combine into one bigger path, or flow in various directions including the opposite direction of most of the paths. The term 'labyrinth' is understood to be structure that has a single-path (unicursal). Thus the labyrinth has only a single, non-branching path, which leads from an inlet to an outlet.

[0020] However, if the second heating volume has a gas flow that is too long, it is disadvantageous in terms of a time lag of the arc interruption with current zero. Another constraint is given by the fact that the longer the second heating volume is, the larger the flow resistance typically is.

[0021] The pressure resistance of the check valve (non-return valve) at the entrance of the first heating volume to the second heating volume may be selected to be lower than the pressure resistance at inlet from pinch pressure chamber to the second heating volume. In any case the check valve ensures that the heated gas does not leave the first heating volume through the second heating volume but through at least one blow channel instead.

[0022] It is further considered advantageous to the interrupting efficiency if the geometry of the gas nozzle in the area of the inlet/entrance to the second heating volume is optimized such that a low flow resistance is achievable.

[0023] As mentioned above, if the second heating volume is at least 20 % as large as the first heating volume, the amount of stored cold gas will cause a significant drop in the gas temperature of the blow gas and thus contribute essentially to an excellent interruption quality. With respect to a well-balanced ratio of time lag of the cold compression and subsequent injection into the first heating volume and the space requirement for the second heating volume, the pressure drop due to the flow resistance of the second heating volume as well as other factors, good interrupting results are achievable if the second heating volume is between about 40% and about 300% as large as the first heating volume.

[0024] A very basic design of an inventive circuit breaker is achievable if the guiding means comprises at least one divider structure for subdividing the second heating volume into a plurality of flow channels that are fluidly disconnected from one another.

[0025] For avoiding dielectric problems occurring after current zero it is advantageous if the second heating volume is arranged in a region of the of the circuit breaker that is displaced from the interruption zone, e.g. axially

displaced with respect to a switching axis, to a region of the circuit breaker where the electric field strength is comparatively low or small.

[0026] Depending on the embodiment of the circuit breaker, the arcing zone is fluidly connected with second heating volume by means of at least one inlet, which inlet is arranged in between the arcing zone and an overpressure valve with respect to a longitudinal direction, e.g. along a switching axis. Moreover, the at least one inlet is arranged either displaced from the overpressure valve, for example in an about centric position between the overpressure valve and the arcing zone, or proximate to the overpressure valve such that the overpressure valve assists feeding heated insulating gas coming from the arcing zone into the at least one inlet.

[0027] In cases where a particularly strong and effective blow gas is required, the electric arc may be interrupted by a circuit breaker comprising two second heating volumes that are arranged along a switching axis on either side of the interruption zone, i.e. such that the first heating volume is located in between them.

[0028] If the heat transfer to the walls gas in the second heating volume shall be reduced and/or if the heated gas shall be of a desired quality within the second heating volume, e.g. cooled, the second heating volume may comprise polytetrafluorethylene (PTFE) or an equivalent material that may be evaporated by the heated gas entering the second heating volume from the arcing zone. Depending on the embodiments, the PTFE may be provided in the second heating volume in form of a surface coatings made of PTFE or a coating comprising PTFE, for example.

[0029] Depending on the demands and the requirements on the circuit breaker, the above-mentioned features may be selected alternatively or in combination.

[0030] The advantages explained above with respect to the inventive method apply likewise to the advantages of the inventive circuit breaker and vice versa.

[0031] Further embodiments, advantages and applications of the present invention will become apparent from claims or claim combinations and when consideration is given to the following more detailed description and the figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The present invention shall be displayed and explained to the person skilled in the art with reference to the following schematic drawings, wherein:

Figure 1 shows a simplified axial longitudinal section through the interruption chamber area of a circuit breaker in accordance with a first embodiment of the invention, wherein the lower half of the longitudinal section is rotated with respect to a switching axis about an angle α such that it leads through an exhaust pipe;

- Figure 2 shows an axial longitudinal section through the interruption chamber area of a circuit breaker in accordance with a second embodiment of the invention, wherein the lower half of the longitudinal section is rotated with respect to a switching axis about an angle α such that it leads through an exhaust pipe;
- Figure 3 shows an axial longitudinal section through the interruption chamber area of a circuit breaker in accordance with a third embodiment of the invention, wherein the lower half of the longitudinal section is rotated with respect to a switching axis about an angle α such that it leads through an exhaust pipe;
- Figure 4 shows a simplified cross-sectional break-out view along section IV-IV of figure 3; and
- Figure 5 illustrates the technical effect of the present invention by a pressure-temperature diagram.

[0033] For purposes of description herein, the terms "upper", "lower", "left", "rear", "right", "front", "vertical", "horizontal", and derivatives thereof shall relate to the invention as oriented in figure 2. However, it is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. In the drawings identical elements or functionally identical elements are given identical reference characters, unless indicated otherwise.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Besides others the following will be mentioned in the detailed description:

In the drawings, like reference numerals designate identical or corresponding parts throughout the several views of the circuit-breaker embodiments, i.e. the consumable switchgear arrangement thereof. As illustrated in **figure 1**, the first embodiment of the circuit breaker is shown in the closed position in the upper half and in the open position in the lower half. The lower half of the longitudinal section is rotated with respect to a switching axis about an angle α such that it leads through an exhaust pipe. If the breaker system has 90° symmetry when seen in the circumferential direction with respect to a switching axis, the angle α may be 45° . However, the angle α may be other than 45° if the breaker system has symmetry other than 90° .

[0035] The circuit breaker has a housing which is es-

entially rotational symmetric about a switching axis 4 and has a first metallic housing part and a second metallic housing part which are connected by a cylindrical middle housing part made from an insulating material. These housing parts are connected in each case to the opposite terminals of the circuit-breaker. Inside that housing there is a consumable switchgear arrangement 1 such as shown in figure 1. Outside the consumable switchgear arrangement 1 there is inter alia a nominal current path comprising stationary and movable nominal current contact members as well as an exhaust volume, partition elements, a switching drive and a puffer volume/system. All these items are not shown since they do not belong to the core of the present invention. For that purpose reference is made to Figure 1 and the description relating thereto in US6163001A, for example.

[0036] The consumable switchgear arrangement 1 comprises a second contact member 2 that is designed as a second tulip contact 2 with a plurality of elastic contact fingers which follow one another in the circumferential direction, are directed obliquely downward and toward the switching axis 4, and are separated by slots. Arranged opposite the second tulip contact 2 there is a second nozzle 3 that surrounds the switching axis 4 and is made from electrically insulating material. The second nozzle 3 has the shape of a funnel flaring towards the left. A slideway (not illustrated) is provided on the left hand side of the second nozzle 3 and houses a movable contact pin 5. Said contact pin 5 can be moved axially along the switching axis 4 by means of the switching drive and projects through the second tulip contact 2 into a first contact member 6 that is likewise formed as a tulip contact in the closed position of the circuit breaker such that the contact members 2, 6 touch the shell surface of the pin 5 with their contact fingers. In this arrangement, said contact fingers are deformed elastically, with the result that they exert a comparatively high contact pressure on the contact pin 5 for ensuring a proper electric contact. The second nozzle 3 is fastened in a central opening in a partition wall of the housing.

[0037] The first contact member 6 is built up similar to the second contact member 2 and is thus attached and neighbored by a first nozzle 7. Also the first nozzle 7 surrounds the switching axis 4 and is also made from electrically insulating material. The first nozzle 7 has the shape of a funnel flaring towards the right and abuts an overpressure valve 8. Different to the closed position of the overpressure valve 8 in the upper half of Figure 1 the lower half shows the overpressure valve 8 in its open position.

[0038] In the open position of the circuit, the contact pin 14 is drawn to the left, with the result that its tip is situated at the left of the second contact member 2. An arcing zone 9 extends between the contact fingers of the second contact member 2 and the first contact member 6 in an arcing chamber such that an electric arc 10 is producible in the arcing zone 9 upon interrupting a current. The arcing zone 9 is surrounded by an annular first

heating volume 13 which is connected to the arcing zone via a gap which separates the tulip contact 2 and the tulip contact and forms a circumferential blow channel 14. The first heating volume 13 is sealed on the outside by a circumferential wall 15 made from insulating material. There are, for example four, puffer volumes distributed over the circumference of the consumable switchgear arrangement at the second nozzle 3. Depending on the embodiment, these puffer volumes have a piston each that can be actuated by the switching drive and are connected each to the first heating volume 13 via blowout channels 16. First non-return valves 17 are installed in each case in the openings of the blowout channels 16 leading into the first heating volume 13.

[0039] When seen in the direction of the switching axis, the arcing zone 9 is arranged next to a pressure chamber 18 that is structurally separated from the arcing zone 9 by the ends of the contact fingers of the tulip contact from the first contact member 6 pointing to the left. The pressure chamber 18 is radially delimited by the tulip contact 6 and a first adjoining annular cover 19 of the first nozzle 7 such that it has the shape of a funnel flaring towards the right. At its right hand side the pressure chamber 18 is delimited by a first adjoining annular cap 20 of the nozzle 7 with the integrated overpressure valve 8 comprising a spring mechanism. In case of excessive gas pressure development in the pressure chamber 18, the overpressure valve opens 8 such that the pressure chamber 18 is hydraulically connected with an exhaust volume allowing the gas to leave the pressure chamber 18 to avoid mechanical damages of the circuit breaker. Depending on the requirements, the overpressure valve 8 may be arranged at a place other than concentrically to the switching axis 4.

[0040] The cover 19 and the cap 20 both feature several axial cavities 21 and 22 respectively wherein the cavities 21 of the cover 19 are radially displaced to corresponding cavities 22 of the cap 20 such that in each case a wall portion 23 (24) that delimits two neighboring cavities 21 of the cover 19 forms a protrusion 23 that is pointing towards the bottom of a corresponding cavity 22 in the cap 20 remains and vice versa. Thus the surfaces of the cover 19 and the cap 20 are facing one another gear or teeth into one another. As a result, the space created between the cap 20 and the cover 19 forms a second heating volume 25 having a labyrinth-style shape with a circumferential gas inlet 31 at the end of the second heating volume 25 proximal to the pressure chamber 18. As a result, the wall portion 23, 24 as well as the gas-touched surfaces of cavities 21, 22 act as guiding means for at least the gas entering the second heating volume from the arcing zone, and to some extent also as guiding means for the cold gas in the second heating volume 25. The interior surface or bottom surface of cavity 21 acts as a first guiding element 21 for guiding heated insulating gas entering the second heating volume 25 from the arcing zone in a first direction 40 towards the a bottom surface of cavity 22 acting as a second guiding element 22.

The second guiding element 22 directs the gas flow in a second direction 41 having an opposite direction component compared to the first direction 40.

[0041] Both the second heating volume 25 and the gas inlet 31 are rotation symmetric with respect to the switching axis 4. In this embodiment the cavities 21, 22 are running fully about the switching axis 4 in the circumferential direction. However, several gas inlets may be provided instead, where required.

[0042] A second non-return valve 26, also referred to as check-valve 26 occasionally, is installed in the opening of a distal end of the second heating volume 25 such that it fluidly connects the second heating volume 25 with the first heating volume 13 if a threshold value is met. In an embodiment, the pre-definable threshold value is met if a gas pressure within the second heating volume 25 exceeds the gas pressure in the first heating volume 13. The first embodiment comprises two second heating volumes 25 that are arranged along a switching axis such that the first heating volume 13 is located in between them. The second heating volume 25 is arranged in a region 35 of the circuit breaker that is axially displaced from the interruption zone 9.

[0043] The entire housing of the consumable switchgear arrangement 1 and its proximity is filled with a suitable insulating gas such as SF₆, for example.

[0044] Compared with the consumable switchgear arrangement disclosed by in US6163001A, the present consumable switchgear arrangement 1 has an improved interrupting efficiency since it comprises two second heating volumes 25 that contribute essentially to the interruption quality, in particular at currents higher than 150kA. For avoiding a lengthy explanation the general set-up of the second heating volume in the second nozzle 3 is the same as in the first nozzle 7. Thus they are given identical or similar reference characters.

[0045] The merely indicated blowout channels 16 of the puffer cylinder are structurally separated from the second heating volume 25 in the second nozzle 3 similar as the exhaust pipes 27 of the first nozzle 7. As shown in figures 1, 2 and 3, such a structural separation is achievable by a pipe, for example.

[0046] Where required, the pressure chamber 18 as well as the interior walls or wall sections of the second heating volume 25 as well as of the first heating volume 13, can be lined with a layer or coating made from a suitable material such as Polytetrafluorethylene, for example, if required. The technical effect of such measure resides in a vaporization of the liner material that increases the quantity of gas and the gas pressure and absorbs energy at the same time, both of which contribute to an improvement in the extinguishing effect.

[0047] If a temperature of the cold gas that is pressurized at the distal end of the second heating volume 25 at the second check valves 26 shall be further decreased further cooling, e.g. by a heat pipe or the like may be required. In figure 1 as well as in subsequent figures, this is achieved by at least one cooling element 28. Since

such cooling elements 28 are optional they are indicated by a dashed line in figure 1.

[0048] Depending on the size and embodiment of the second heating volume 25 an undesired gas movement of the cold gas and the heated gas entering the second heating volume from the pressure chamber in the circumferential direction with respect to the switching axis may be prevented or at least limited by providing at least one divider 29 in at least a portion of the labyrinth-shaped second heating volume 25, preferably at its distal end region at the second check valve 26. In a basic embodiment these dividers 29 are formed by sheet-like walls 29 that may be inserted in corresponding slots (not shown in figure 1) during the assembly stage of the annular cap 20 on the annular cover 19. Alternatively the dividers can be integrated in the cap 20 and/or the cover 19 if required. Depending on the requirements these sheet-like dividers 29 are oriented radially with respect to the switching axis 4. In figure 1, these dividers 29 divide the cavities 21 in the cover 19 only and extend in the direction of the switching axis 4 (in the first nozzle 7 towards the overpressure valve 4 to the right) merely to a front edge 33. However, in other embodiments the dividers may extend along the full length of second heating volume, wherein the term length is understood as the flow path of the insulation gas from the pressure chamber 18 gas through the nozzle.

[0049] If such dividers 19 are employed they also act as gas guiding means according to the gist of the present application.

[0050] In case of a comparatively low height 30 of the labyrinth relative to its cross-section seen in the direction of the switching axis 4, no dividers 29 may be required for ensuring that the gas entering the second heating volume 25 from the arcing zone 9 is not mixing with the stored amount of insulating gas in the second heating volume 25, in particular near the second check-valve 26 excessively. For that reason, the dividers 29 are optional for the embodiment shown in figure 1 and are thus indicated by a dashed line in figure 1.

[0051] An opening operation of the consumable switchgear arrangement proceeds as follows:

In case of interrupting so-called low current arcs of currents smaller than about 50kA, the electric arc does not cause sufficient, i.e. substantial backheating in the first heating volume 13 and second heating volume 25. Thus the electric arc is interrupted by assistance of a pressure chamber, e.g. a puffer system that injects gas into the first heating volume 13 via the first valves 17. The second check-valves 26 are in their retracted (closed) position such that the gas is forced to leave the first heating volume 13 through the blow channel formed by the annular gap 14.

[0052] In case of medium current arcs of currents larger than about 50kA but smaller to about 80kA as well as

high currents of about a 100kA to about a 150kA (i.e. below highest currents) such medium or high currents cause sufficient backheating in the first heating volume 13 for interrupting the electric arc 10 without assistance of the puffer system. In this case the pinch effect contributes already to the interruption process by backheating of the gas in the second heating volume 25. However, the share of the interruption efficiency contributed by the second heating volume 25 is smaller than the share of the first heating volume 13.

[0053] At so-called highest currents of a 150kA to about 200kA the electric arc causes full pinch conditions where a pinch pressure caused by the electric arc 10 is very powerful. At these highest currents the electric arc causes substantial backheating in second heating volume 25 causing a substantial cold compression therein. As a result a blow temperature of the gas being ready for interrupting the electric arc is less than a 2000 Kelvin. Note, that the blow gas comprises of the gas pressurized in the first heating volume 13 by the arc directly and the pressurized cold gas from the second heating volume 25. At highest currents, the share of the interruption efficiency contributed by the second heating volume 25 is larger than the share of the first heating volume 13.

[0054] Although the first embodiment of the consumable switchgear arrangement shown in figure 1 comprises two nozzles 3, 7 and two second heating volumes 25 an alternative embodiment may be suitable that has only one second heating volume, e.g. a second heating volume such as the one provided in between the first contact member 6 and the first annular cap 20.

[0055] A similar embodiment of such a circuit breaker is described with reference to **figure 2** showing a second embodiment of the inventive circuit breaker. For avoiding lengthy repetitions of the elements, their functions and effects resulting thereof the applicant refers is made to the explanations provided for the first embodiment shown in figure 1. Hence such elements are given like reference numerals in figure 2. Hereinafter the focus is put on the differences of the second embodiment 1a shown in figure 2 compared to the first embodiment 1 of the circuit breaker.

[0056] The second embodiment 1a features only one nozzle 7a arranged on the right hand side of the arcing zone 9. Thus, the blow channels 16 are integrated in the second contact member 2.

[0057] In the second embodiment 1a, the arcing zone 9 is fluidly connected with the second heating volume 25 by means of the gas inlet 31a. Both the second heating volume 25 and the gas inlet 31a are rotation symmetric with respect to the switching axis 4. The gas inlet 31a is arranged in between the arcing zone 9 and the overpressure valve 8 with respect to the longitudinal direction defined by the switching axis 4, wherein the gas inlet 31a is arranged in a displaced manner from the overpressure valve 8 between the latter and the contact fingers of the second contact member 6. However, several gas inlets may be provided instead, where required.

[0058] Since the overpressure valve 8 delimits the pressure chamber 18 longitudinally at one end the heated gas entering the delimits the pressure chamber 18 from the arcing zone 9 can leave the pressure chamber 18 normally through that gas inlet 31a mainly, except in case of excessive overpressure where the gas is allowed to leave the pressure chamber 18 directly to the exhaust 32.

[0059] Again, depending on the cross-section and the size of the second heating volume 25, dividers 29 may be required for suppressing or avoiding undesired gas flow of cold and heated gas in the second heating volume 25 such that the gases mix, in particular in a distal region of the second heating volume 25 at the second check-valves 26.

[0060] An advantage of the second embodiment 1a and in particular its second heating volume 25 compared to the first embodiment 1 resides in that it is easier to produce since its geometrical complexity is lower than the one of the first embodiment 1. On the other hand the overall length of the gas flow path formed by the labyrinth-shaped second heating volume 25 is shorter than in the first embodiment 1.

[0061] A third embodiment 1b of the inventive circuit breaker is discussed hereinafter with reference to **figure 3** and **figure 4**. Hence, the following explanation is based on a comparison of the third embodiment 1b and the second embodiment 1a of the circuit breaker and its consumable switchgear arrangement. For avoiding lengthy repetitions of the elements, their functions and effects resulting thereof the applicant refers is made to the explanations provided for the first and second embodiment shown in figures 1 and 2 respectively. Hence such elements are given like reference numerals in figure 3, too. Hence, the focus is put on the differences of the third embodiment 1b to the second embodiment 1a of the circuit breaker.

[0062] To start with, the third embodiment 1b features only one nozzle 7b arranged on the right hand side of the arcing zone 9. The blow channels 16 are integrated in the second contact member 2. Moreover, the gas inlet 31b is arranged proximate to the overpressure valve 8 such that a 34 of the overpressure valve 8 assists guiding the heated insulating gas coming from the arcing zone 9 into the inlet 31b. For supporting an optimal gas flow through the inlet 31b the piston 34 of the overpressure valve 8 is shaped accordingly thus contributing to low flow resistance values and a small loss in pressure. Again, both the second heating volume 25 and the gas inlet 31b are rotation symmetric with respect to the switching axis 4. However, several gas inlets may be provided instead, where required.

[0063] In the third embodiment 1b, the height 30a of the second heating channel 25 relative to its cross-section seen in the direction of the switching axis 4 is larger than in the first or second embodiment 1, 1a. Since a larger height is prone to leading to undesired gas movements and thus gas mixture within the second heating volume 25 in a circumferential direction with respect to

the switching axis 4, several dividers 29a have been provided. As shown in the cross-sectional along plane IV-IV of figure 3 in the simplified figure 4, eight dividers 29a are arranged in the third embodiment 1b in an equal circumferential displacement to one another and with a radial orientation with respect to the switching axis 4. As shown in figures 3 and 4, a length of the dividers extends along almost the full length of the second heating volume 25, wherein the term length is understood as the flow path of the insulation gas from the pressure chamber 18 gas through the nozzle 7b. As a result, the front edges 33 of the dividers 29a which reach to the area where the piston 34 of the overpressure valve 8 is located become visible in figure 3. In this embodiment 1b the longitudinal guiding of at least the heated insulating gas entering the second heating volume 25 from the arcing zone 9 is performed by the bend in between the axial portion 36 and the radial portion 37 of the second heating volume 25 by the interior surface of the first nozzle 7b whereas the guiding of the gas in the circumferential direction with respect to the switching axis 4 is performed by the dividers 19.

[0064] An alternative divider arrangement is shown in the lower half of figure 4 wherein every second divider 29b is designed to have a shorter length than the remaining dividers 29a in an alternating manner. As the dividers 29a mentioned earlier, also these second dividers 29b divide the second heating volume 25 in sub-sections at a proximal end of the second heating volume 25 at the check-valves 26 but their length does extend just before the bend region where a horizontal portion of the second heating volume 25 joins a radial portion 37 thereof. A representative zone where a front edge 33a of such a second divider 29b may be located is indicated in the lower half only in order to avoid confusion and for improving the understandability of figure 3. In this third embodiment 1b, the dividers 29a (29b) and the first annular cover 19 are made from one piece, i.e. are single-bodied.

[0065] Depending on the requirements on the exhaust pipes 27, they may be funnel-shaped such as shown in figure 4 or straight such as shown in figure 3, wherein only the straight version was displayed for simplicity. In figure 4 only one exemplary exhaust pipe 27 provided in the lower half is shown whereas further exhaust pipes have been omitted for enhanced readability and clarity of figure 4.

[0066] Besides the partitioning of the second heating volume 25, figure 4 shows the shape of the second heating volume 25 at the proximal end of the second heating volume 25 at the check-valves 26. Said shape corresponds to an annular ring a section. Depending on the embodiment of the check-valves 26, the same may apply to them likewise. For the sake of clarity and better understandability the check-valves 26 have not been displayed in the lower half of figure 4.

[0067] Compared to the embodiment 1a, the embodiment 1b is even easier to manufacture since the geometry of the nozzle 7b is even more basic than the one of

the nozzle 7a shown in figure 2.

[0068] Figure 5 illustrates schematically the technical effect of the present invention by a pressure-temperature diagram, wherein the abscissa denotes the gas pressure within the first heating volume and wherein the ordinate represents the temperature of the blow gas within the first heating volume. The 2000 Kelvin-line denotes a borderline above which the dielectric abilities of the insulation gas SF₆ typically becomes electrically ineffective. Curve one 38 represents a pressure-build up in the first heating volume 13 resulting of a pre-compression of about 6 bar in the second heating volume. Curve two 39 represents a pressure-build up in the first heating volume 13 resulting of a pre-compression of about 20 bar in the second heating volume. As a result, the diagram clearly displays that the amount of the cold-compression forms a substantial factor for the interruption quality, in particular if highest electric arcs resulting of currents above 150kA are to be interrupted where highest blow gas pressures are required. In this diagram, the enhancement of the pre-compression of the cold gas from 6 bar to 20 bar within the second heating volume prior to leading it into the first heating volume allows more than doubling the pressure build-up in the first heating volume without affecting the blow gas temperature excessively. If an even higher pre-compression, i.e. cold compression is achieved within the second heating volume, an even higher pressure build-up within the first heating volume is achievable.

[0069] It will be apparent to those skilled in the art, based upon the teachings herein, that changes and modifications may be made without departing from the disclosure and its broader aspects. That is, all examples set forth herein above are intended to be exemplary and non-limiting.

List of reference numerals

[0070]

1, 1a, 1b	consumable switchgear arrangement
2	second contact member, second tulip contact
3	second nozzle
4	switching axis
5	pin
6	first contact member, tulip contact
7, 7a, 7b	first nozzle
8	overpressure valve
9	arcing zone

10	electric arc
13	first heating volume
14	blow channel
15	circumferential wall
16	blowout channel from puffer volume
17	first non-return valves
18	pressure chamber
19	annular cover
20	annular cap
21	axial cavity in annular cover
22	axial cavity in annular cap
23	wall portion of the cover
24	wall portion of the cap
25	second heating volume
26	second non-return valves (check-valves)
27	exhaust pipe
28	cooling element
29, 29a, 29b	divider
30, 30a	radial height of the second heating volume
31, 31a, 31b	gas inlet
32	exhaust
33, 33a	front edge of divider
34	piston of overpressure valve 8
35	region
36	axial portion of second heating volume
37	radial portion of second heating volume
38	curve one
39	curve two

- 40 first direction
- 41 second direction

Claims

1. A circuit breaking method, comprising the following steps:

- a) Providing a gas-blown circuit breaker (1, 1a, 1b) having an interruption chamber filled with an insulating gas, said interruption chamber comprising an arcing zone (9) and at least two separable arcing contacts (2, 6);
- b) Storing an amount of insulating gas in a second heating volume (25) of the interruption chamber, said second heating volume (25) being fluidly connected with the arcing zone (9) and fluidly connectable with a first heating volume (13), wherein said first heating volume (13) is fluidly connected with the arcing zone (9);
- c) Separating the arcing contacts (2, 6) from one another such that an electric arc (10) is generated between said arcing contacts (2, 6) and such that a gas pressure caused by the electric arc (10) in the second heating volume (25) is higher than about 3 bar relative to a nominal gas pressure;
- d) Pressurizing the amount of insulating gas in the second heating volume (25) by heated insulating gas entering the second heating volume (25) from the arcing zone (9);
- e) Guiding at least the heated insulating gas entering the second heating volume (25) from the arcing zone (9) at least during step d) such that the heated insulating gas entering the second heating volume (25) from the arcing zone (9) is suppressed from mixing with the stored amount of insulating gas in the second heating volume (25) by a gas guiding means (23, 24, 29, 29a) of the second heating volume (25), wherein the second heating volume (25) is at least 20% as large as the first heating volume (13);
- f) Injecting the amount of insulating gas stored in the second heating volume (25) into the first heating volume (13) by a gas pressure applied on the gas stored in the second heating volume (25) by the heated insulated gas coming from the arcing zone (9) into the first heating volume (13);
- g) Interrupting the electric arc (10) by leading the insulating gas from the first heating volume (13) back into the arcing zone (9) through at least one blow channel (14).

2. The method according to claim 1, wherein the second heating volume (25) is at least 40 % as large as

the first heating volume (13) and/or wherein the electric arc (10) is in a pinch mode in step c.

3. The method according to claim 1 or 2, wherein the gas guiding means (21, 22, 23, 24, 29, 29a)

- a) Comprises a first guiding element (21) for guiding heated insulating gas entering the second heating volume (25) from the arcing zone (9) in a first direction (40), and a second guiding element (22) for guiding insulating gas leaving a first portion with the first guiding element (21) in a second direction (41), wherein the first direction (40) and the second direction (41) have opposite direction components; and/or
- b) subdivides the second heating volume (25) in a plurality of gas channels that are fluidly disconnected from one another.

4. The method according to anyone of claims 1 to 4, further **characterized by** actively cooling at least one of the insulating gases stored in the second heating volume (25) and the gas entering the second heating volume (25) from the arcing zone (9).

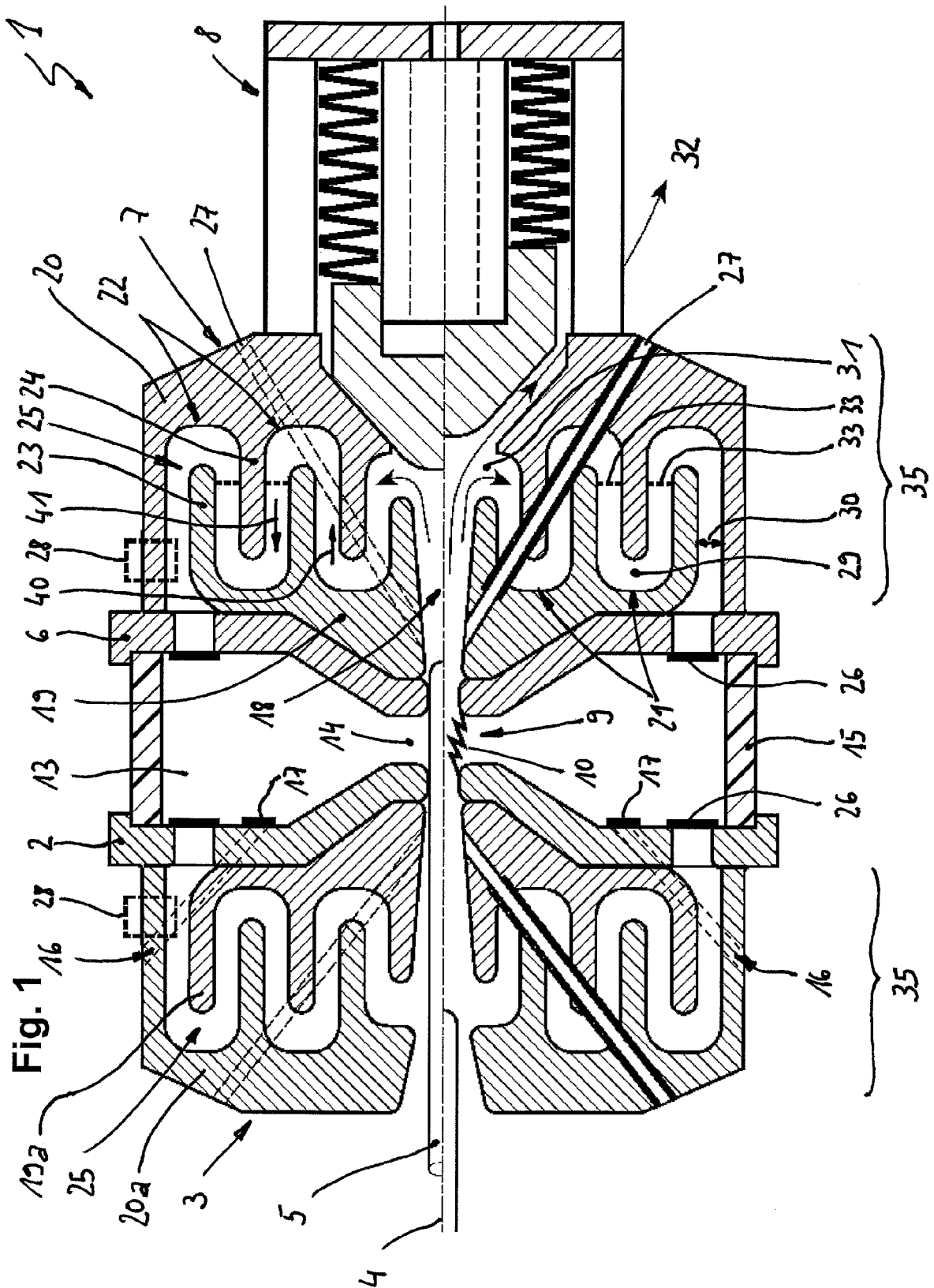
5. A circuit breaker (1, 1a, 1b) comprising an interruption chamber filled with an insulating gas, at least two separable arcing contacts (2, 6) defining an arcing zone (9) in which an electric arc (10) is producible in between the at least two separable arcing contacts (2, 6) during a circuit interruption process, wherein the interruption chamber comprises a first heating volume (13) that is fluidly connected with the arcing zone (9) and a second heating volume (25) that is fluidly connected with the arcing zone (9), and wherein said second heating volume (25) is fluidly connectable with the first heating volume (13) via a check valve (26) that opens if a gas pressure in the second heating volume exceeds a predefined value, **wherein** the second heating volume (25) is at least 20% as large as the first heating volume (13), and in that the second heating volume (25) comprises a guiding means (23, 24, 29, 29a) for guiding at least the heated insulating gas entering the second heating volume (25) from the arcing zone (9) such that the heated insulating gas entering the second heating volume (25) from the arcing zone (9) is suppressed from mixing with an amount of insulating gas stored in the second heating volume (25) prior to the circuit interruption process.

6. The circuit breaker according to any one of claims 5 to 7, wherein the guiding means (21, 22, 23, 24) comprises a first guiding element (21) for guiding heated insulating gas entering the second heating volume (25) from the arcing zone (9) in a first direction (40), and a second guiding element (22) for guiding insulating gas leaving the first portion with the first guiding

element (21) in a second direction (41) differing to the first direction (40), wherein the first direction (40) and the second direction (41) have opposite direction components.

7. The circuit breaker according to claim 5 or 6, wherein the second heating volume (25) forms a flow path that has a meander or labyrinth-like appearance. 5
8. The circuit breaker according to any one of claims 5 to 7, wherein the guiding means (29, 29a) comprises at least one divider structure for subdividing the second heating volume into a plurality of flow channels that are fluidly disconnected from one another. 10
9. The circuit breaker according to any one of claims 5 to 8, wherein the second heating volume (25) is at least 40 % as large as the first heating volume (13). 15
10. The circuit breaker according to any one of claims 5 to 10, wherein the second heating volume (25) is between about 40% and about a 300% as large as the first heating volume (13). 20
11. The circuit breaker according to any one of claims 5 to 10, wherein the second heating volume (25) is arranged in a region (35) of the circuit breaker that is displaced from the interruption zone (9). 25
12. The circuit breaker according to any one of claims 5 to 11, wherein the second heating volume (25) comprises polytetrafluorethylene. 30
13. The circuit breaker according to any one of claims 5 to 12, wherein the second heating volume (25) comprises at least one cooling element (28), in particular at least one of a cooling fin and a heat exchanger, for actively cooling at least one of the insulating gas stored in the second heating volume (25) prior to the circuit interruption process and the heated insulating gas entering the second heating volume (25) from the arcing zone (13). 35 40
14. The circuit breaker according to any one of claims 5 to 12, wherein the arcing zone (9) is fluidly connected with the second heating volume (25) by means of at least one inlet (31, 31a, 31b), which inlet (31, 31a, 31b) is arranged in between the arcing zone (9) and an overpressure valve (8) with respect to a longitudinal direction, wherein the at least one inlet (31, 31a, 31b) is arranged 45 50
 - a) Displaced from the overpressure valve (8); or
 - b) proximate to the overpressure valve (8) such that the overpressure valve (8) assists feeding heated insulating gas coming from the arcing zone (9) into the at least one inlet (31b). 55

15. The circuit breaker according to any one of claims 5 to 13, wherein two second heating volumes (25) are arranged along a switching axis such that the first heating volume (13) is located in between them.



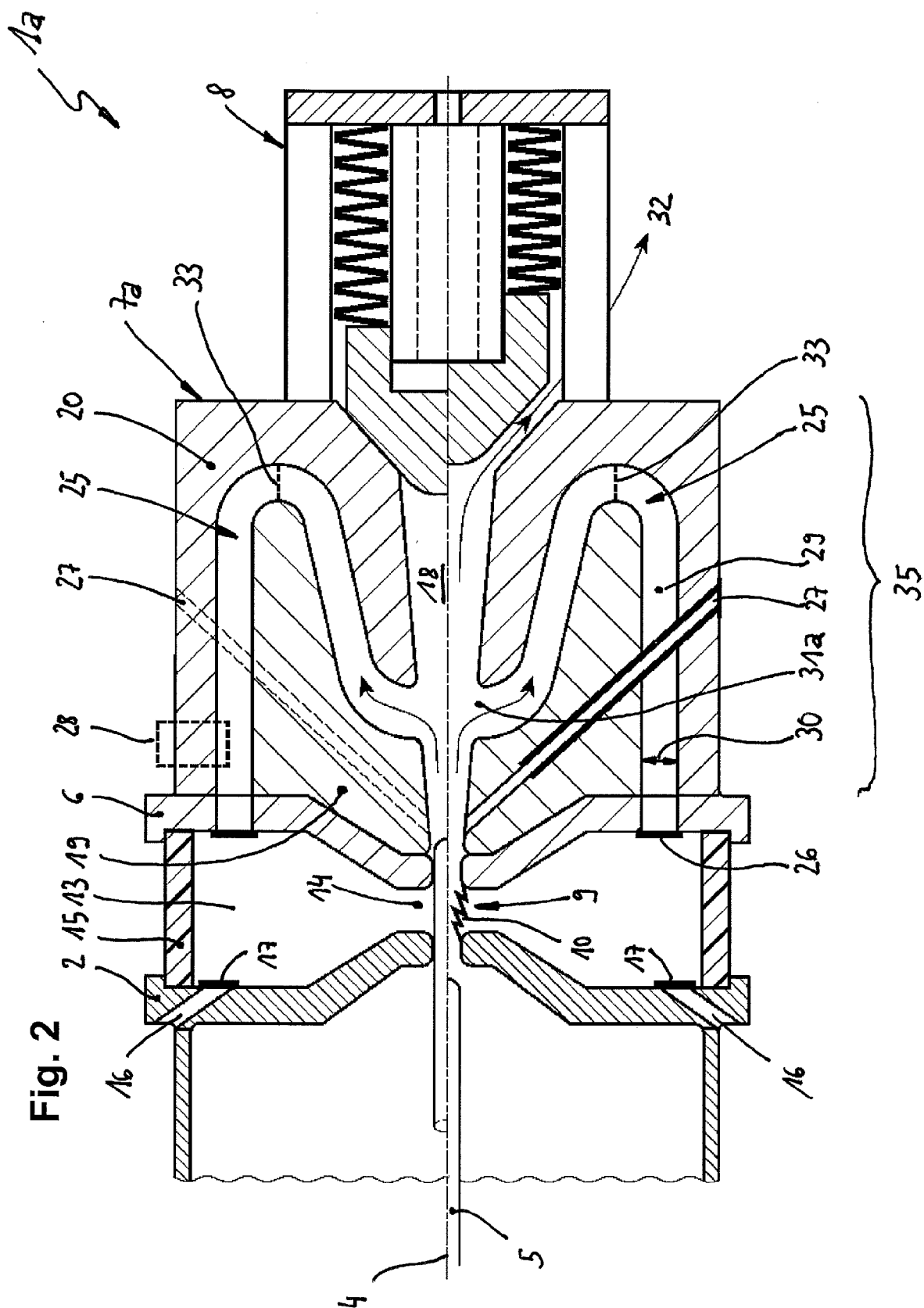


Fig. 4

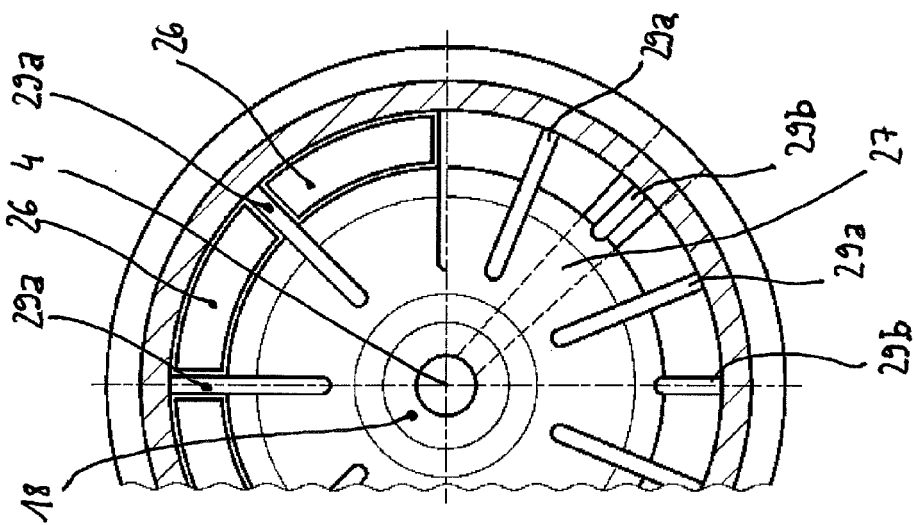


Fig. 3

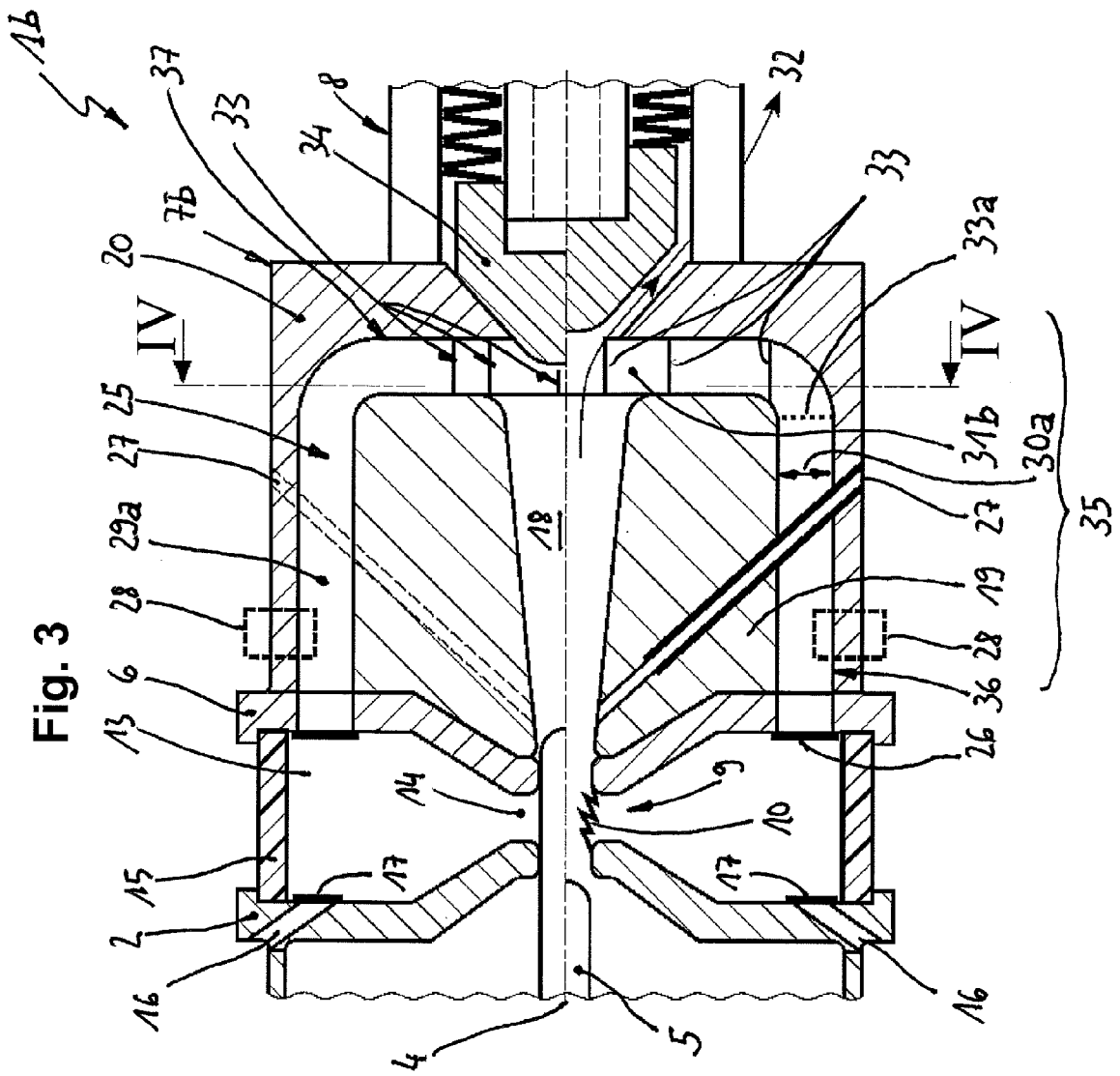
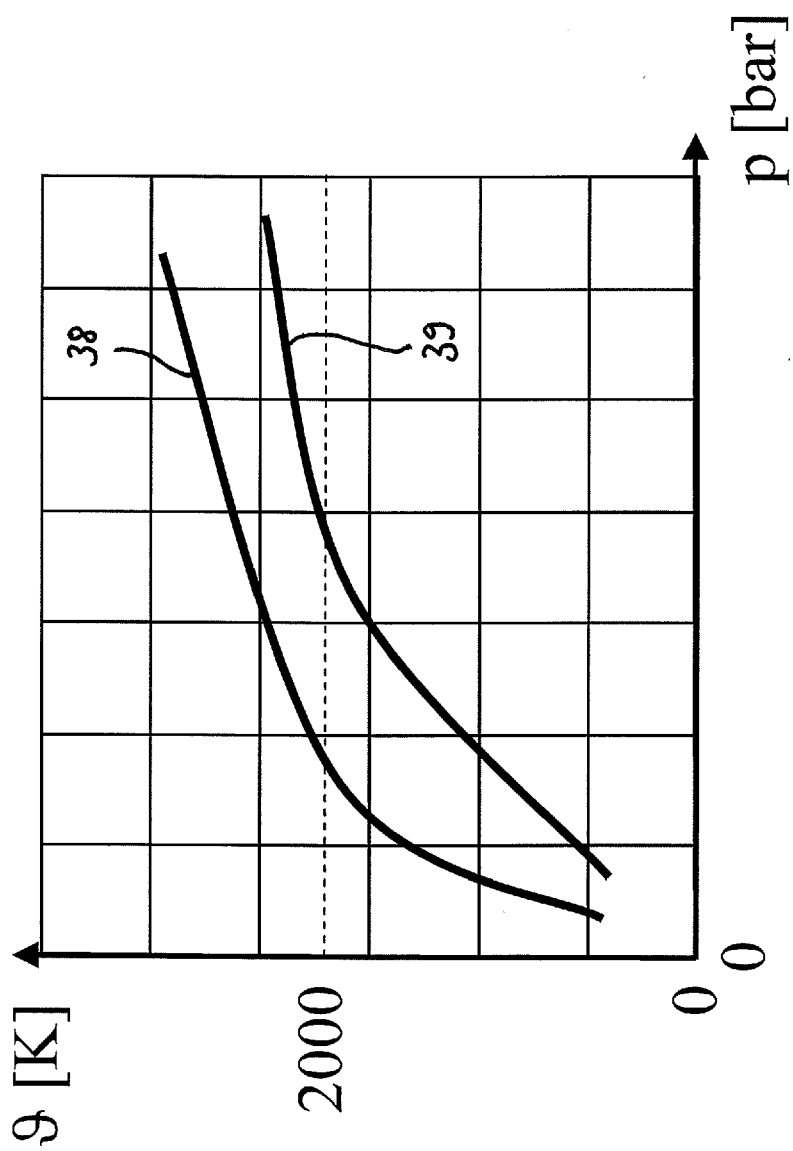


Fig. 5





EUROPEAN SEARCH REPORT

Application Number
EP 10 19 2018

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	US 4 684 773 A (NIEMEYER LUTZ [CH]) 4 August 1987 (1987-08-04)	1-3, 5-12,14, 15	INV. H01H33/98
A	* column 3, line 26 - column 4, line 25; figure 1 *	4,13	
A,D	----- US 6 163 001 A (ZEHNDER LUKAS [CH] ET AL) 19 December 2000 (2000-12-19) * abstract; figure 2 * -----	1,5	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01H
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 13 April 2011	Examiner Simonini, Stefano
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 10 19 2018

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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13-04-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4684773 A	04-08-1987	CN 85107522 A	20-08-1986
		DE 3440212 A1	17-04-1986
		DE 3584494 D1	28-11-1991
		EP 0177714 A2	16-04-1986
		ES 8700495 A1	01-01-1987
		IN 165779 A1	06-01-1990
		JP 2089221 C	02-09-1996
		JP 8001774 B	10-01-1996
		JP 61091811 A	09-05-1986
		ZA 8506654 A	30-04-1986
US 6163001 A	19-12-2000	CN 1232280 A	20-10-1999
		DE 19816505 A1	21-10-1999
		EP 0951039 A1	20-10-1999
		JP 11329191 A	30-11-1999

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6163001 A1 [0002] [0010] [0011] [0012]
- EP 1225610 B1 [0002] [0010] [0011] [0012]
- US 6163001 A [0035] [0044]