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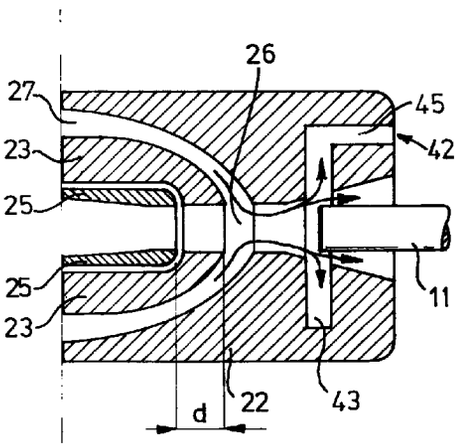
(54) Method for extinguishing an arc in a power circuit-breaker by means of a gas stream, and power circuit-breaker

(57) The invention relates to a method for extinguishing an arc which is formed during the breaking of the electrical contact in a power circuit-breaker of the puffer type, by means of a gas stream, such as an SF_6 gas stream. The gas stream comes from a pressure chamber which is placed in connection with the arc. The electrical contact is broken by separating two contacts from one another and then moving them further apart. The connection between the arc and the pressure chamber is established after a predetermined delay time after the contacts have been separated or after the contacts have been separated from one another by a predetermined distance. The invention furthermore relates to a power circuit-breaker of the puffer type, which is suitable in particular for carrying out the method according to the invention. To this end, the circuit breaker comprises closure means for closing and opening the pressure-chamber outlet, which closure means are designed in such a manner that the pressure-chamber outlet is closed at the moment at which the moveable contacts are separated from one another and is opened after a predetermined delay time or after the contacts have been separated from one another by a predetermined distance.

Fig - 6



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Description

[0001] The present invention relates to the field of power circuit-breakers. In this context, power circuit-breakers are understood to mean in particular contact breakers across which there is a high voltage, such as a high voltage of 50 kV and more, after the electrical contact has been broken.

[0002] The present invention relates more particularly to a method for extinguishing an arc which is formed during the breaking of the electrical contact in a power circuit-breaker, such as a circuit-breaker of the puffer type, by means of a gas stream, such as an SF_6 gas stream, the gas stream coming from a pressure chamber which is placed in connection with the arc, and the electrical contact being broken by separating two contacts from one another and then moving them further apart.

[0003] A method of this nature and circuit-breakers which operate using a method of this nature are known from the prior art, cf. for example DT-2,620,675, US-4,160,888 and EP-A2-503,223.

[0004] The above mentioned publications all show a method and circuit-breaker of the puffer type in which an extinguishing gas, also known as puffer gas, is used to extinguish the arc which is formed when the contact is broken between two contacts which can be separated from one another and moved apart and across which there is a high voltage after the contact has been broken. In such circuit-breakers, use is made of a pressure chamber in which the extinguishing gas which is to be used to extinguish the arc is situated, which gas is pressurized by means of a piston, and possibly utilizing the arc energy, in order to be able to extinguish the arc by blowing, also known as puffing.

[0005] Since circuit-breakers of this nature are also intended in particular to break the contact in the event of disasters, it is extremely important that this is able to take place quickly and efficiently. Since one of the consequences of the arc is that the contact is maintained as long as the arc exists, it is important here to extinguish the arc as quickly as possible. This can be achieved, on the one hand, by extinguishing the arc which is formed as quickly as possible, an operation for which, as is known from the prior art, a gas stream which has been brought about as a result of a pressure difference is eminently suitable, and, on the other hand, by pulling the contacts apart as quickly as possible until a sufficient distance has been reached for it to be ensured that after the arc has been extinguished it is not possible for another arc to be formed within the gas employed.

[0006] The method and device according to the preambles of Claims 1 and 8, respectively, are also known from EP-A-741,399, which discloses a "gas electric high-tension interrupter of the arc-puffer type". When, in the method or device according to EP-A-741,399, the contacts (3) and (1) come away from one another, the result is, on the one hand, an arc and, on the other hand, at the same time an immediate connection between the said arc and the pressure chamber. The opening (18) of the pressure chamber is partly delimited by the fixed contact. EP-A-7-41,399 does not make any mention of there being a delay in bringing about the connection between the arc and the pressure chamber.

[0007] Furthermore, US-A-3,659,065 discloses a "fluid-blast circuit interrupter", in which there is a fixed arc-striking contact (43), a moveable contact (35) and a pressure chamber (31) in which pressure is built up by means of a moveable piston (26). According to the brief description, Figure 2 of this US-A-3,659,065 shows a "considerably enlarged longitudinal sectional view". Therefore, dimensions shown in this Figure 2 are considerably greater than those to be found in reality, i.e. the device illustrated in Figure 2 of the US-A-3,659,065 has, in its practical form, relatively small dimensions.

[0008] The object of the present invention is to provide an improved method for extinguishing an arc in a power circuit-breaker and to provide a power circuit-breaker of this nature, the reliability of the method or circuit-breaker and the speed with which the contact is broken being of particularly great importance.

[0009] With regard to the method, this object is achieved by the fact that the connection between the arc and the pressure chamber is brought about:

- at a predetermined time after the contacts have been separated from one another and while they are moving further apart; or
- after the contacts have been separated from one another by a predetermined distance.

It can thus be ensured that the gas stream is only released onto the arc when the gas stream is able to extinguish the arc, which will then take place at the first current zero crossing after the gas stream has been released. Incorporating a delay between the time at which the arc begins to form and the time at which a gas stream is released onto it ensures that the arc has a certain minimum length at the moment at which the gas stream is released onto it, so that the arc is permanently extinguished by the gas stream after the first visible current zero crossing following the time delay. The same effect, namely a certain minimum length of the arc at the moment at which the gas stream is released onto it, can also be achieved by only releasing the gas stream onto the arc when the contacts have been separated from one another by a predetermined distance, so that the arc therefore has a certain minimum length. The predetermined time or the predetermined distance will therefore preferably be such that the arc is permanently extinguished at the moment of the first current zero crossing following the establishment of the connection between arc and pressure chamber. The invention is based on the insight that, by increasing the length of the arc, it can be extinguished more easily by means of a flow of a pressurized gas which is suitable for this pur-

pose. If the gas stream is released onto the arc too early, there is a risk of the arc not being extinguished or being extinguished incompletely when a current zero crossing occurs and of the arc then re-establishing itself after the current zero crossing so as to be subjected, during the following current zero crossing, to a subsequent extinguishing attempt which will be less effective/less likely to succeed owing to the first, unsuccessful extinguishing attempt and the pressure lost during this attempt.

[0010] According to the invention, a reliable extinguishing action is obtained if the predetermined time is longer than 1.5 msec, and preferably lies in the range from approximately 1.5 msec to approximately 15 msec. Working on the basis of a predetermined time of 2 msec, this then means that the gas stream is released onto the arc 2 msec after the arc begins to form (i.e. after the contacts come apart), so that the arc can be completely extinguished during its next zero crossing, the extinguished current zero crossing, i.e. at least for a mains frequency of 50 Hz, somewhere in the range from 2 msec to 12 msec after the contacts come apart. In the case of a power circuit-breaker for 72.5 kV and 31.5 kA the predetermined time will preferably lie within the range from 1.5 to 10 msec.

[0011] It has been found that the method according to the invention is reliable if the speed at which the contacts move further apart lies at least within the range from approximately 1 to 10 m/sec or higher.

[0012] Furthermore, it has been found, according to the invention, that the arc can be reliably extinguished if the predetermined distance by which the contacts are separated from one another when the gas stream is released onto the arc is at least approximately 5 and preferably less than 105 mm and, at least for power circuit-breakers of 72.5 kV and 31.5 kA, preferably lies in the range from approximately 8 to approximately 40 mm. In view of the usual size of power circuit-breakers of this nature, such a distance is relatively short, so that a predetermined distance of this level is acceptable without having a significant adverse effect on the compactness of the structure.

[0013] According to the invention, it is particularly advantageous if the predetermined distance lies in the range which is defined by the equation

$$d = a^3 \cdot U \cdot I,$$

where:

d = the predetermined distance in m
a = constant lying within the range of approximately $1.5 \cdot 10^{-4}$ to approximately $2.6 \cdot 10^{-4}$
with, as the unit

$$\left(\frac{W}{m}\right)^{-\frac{1}{3}}$$

U = the system voltage in V
I = short-circuit current in A to be disconnected.

Using this equation makes it easy to determine the predetermined distance, taking into account the so-called system voltage, the short-circuit current to be disconnected and further system parameters defined by the system, which parameters are dealt with using the empirically determined range for the parameter a. In this context, system voltage is understood to mean the voltage level for which the power circuit-breaker is used.

[0014] The pressure chamber may already be pressurized before the contact breaker is disconnected, i.e. before the two contacts even start move. In this case, in terms of the pressure chamber it is possible to give consideration to a pressure source which is permanently at a sufficient pressure. In order to ensure that, in the event of an emergency, the contacts can immediately be broken at any time after they have been connected, in this case the pressure chamber will preferably be at sufficient pressure even before the contacts have been connected. To establish the connection between the arc and the pressure chamber, it is possible, by way of example, to use an actuable valve. However, a design of this nature can easily entail the drawback that the excess pressure in the pressure chamber may fall, for example as a result of gas leaking past the actuable valve or the closure means for the connection between the arc and the pressure chamber. However, it has been found that the switching movement, in which the contacts are moved apart, and possibly also the arc energy, can be used, when breaking the contact, to built up and/or increase the pressure in the pressure chamber while the contacts are moving apart. Another conceivable embodiment involves building up the pressure in the pressure chamber by means of the switching movement and compensating for the possibility of a higher counteract-pressure as a result of the arc energy in the arc area by using some of the arc energy to provide an additional increase in pressure in the pressure chamber. In this case, the switching movement and/or the arc energy may be used instead of or in addition to an excess pressure which is already present more or less permanently in the pressure chamber before the contact is broken.

[0015] According to a particular embodiment, the reliability of the method according to the invention can be increased in particular if the connection between the pressure chamber and the arc is opened by moving one of the two contacts which move apart past an outflow opening of the pressure chamber. This makes separate valves, which could go wrong, superfluous. In this case, one of the two contacts which move apart is used as the closure member which, after it has moved passed outflow opening of the pressure chamber, ensures that the gas stream is released onto the arc. As soon as the arc has then had a current zero crossing, the gas stream is able to extinguish the arc.

[0016] In addition to a method for extinguishing an arc

in a circuit-breaker, the invention also relates, in particular, to a circuit-breaker which can be used to extinguish an arc effectively and reliably. The invention therefore also relates in particular to a power circuit-breaker of the puffer type, comprising:

- two contacts which can be separated from one another and moved apart, and between which an arc can be formed in an arc area after the separation and the following movement further apart;
- a pressure chamber which is provided with a pressure-chamber outlet and in which a pressurized gas may be situated during separation of the contacts;

the opening of the pressure-chamber outlet being situated at the edge of the arc area, in such a manner that pressurized gas from the pressure-chamber outlet can act on any arc which may be present, characterized in that the power circuit-breaker furthermore comprises closure means for closing and opening the pressure-chamber outlet, which closure means are designed in such a manner that the pressure-chamber outlet is closed at the moment at which the moveable contacts are separated from one another and is opened:

- at a predetermined time after the contacts have been separated and while they are moving further apart; or
- after the contacts have been separated from one another by a predetermined distance.

The advantages of such a power circuit-breaker of the puffer type will be clear from the advantages which have already been disclosed above of the method according to the invention for extinguishing an arc.

[0017] Just as in the method according to the invention, in an advantageous embodiment of the power circuit-breaker, the predetermined time will be longer than approximately 1.5 msec and will preferably lie in the range from approximately 1.5 msec to approximately 15 msec.

[0018] Furthermore, likewise in accordance with an advantageous embodiment of the method, the power circuit-breaker will advantageously be designed to move the contacts apart at a speed of approximately 1 to 10 m/sec or higher.

[0019] As in the method according to the invention, in an advantageous embodiment of the power circuit-breaker the predetermined distance will be at least approximately 5 mm, preferably less than approximately 105 mm, such as a value lying within the range from approximately 8 mm to approximately 40 mm.

[0020] Again, as for the method according to the invention, the predetermined distance will advantageously lie in the range which is defined by the equation:

$$d = a^3 \cdot U \cdot I,$$

where:

d = the predetermined distance in m
a = constant lying within the range of approximately $1.5 \cdot 10^{-4}$ to approximately $2.6 \cdot 10^{-4}$ with, as the unit

$$\left(\frac{W}{m}\right)^{-\frac{1}{3}}$$

U = the system voltage in V
I = short-circuit current in A to be disconnected.

[0021] If a power circuit-breaker furthermore comprises a sleeve which is made of insulating material and is provided with a contact passage through which one of the contacts can be moved when they are being separated and then moved apart, the pressure-chamber outlet extending through the sleeve so that its opening opens out into the contact passage, according to an advantageous embodiment of the invention the sleeve around the opening encloses one of the contacts when this contact is situated at least in front of the opening so as to form the closure means together with the said one of the contacts. Thus, one contact can act as an opening member for opening, the passage from the pressure chamber, also referred to as the puffer chamber or pressure space, to the arc in order to be able to release the gas stream onto the arc. If the other contact is in this case a fixed, stationary contact, the distance from the opening to this fixed contact will preferably correspond to the predetermined distance between the contacts at the moment at which the gas stream is released onto the arc, which predetermined distance, according to an advantageous embodiment, is 5 to 105 mm, such as for example approximately 10 mm to approximately 100 mm. However, it will be clear that this other contact does not have to be a fixed contact, but rather, according to a further advantageous embodiment, the sleeve may also be fixed with respect to the other of the contacts, in which case the contact passage extends from outside the sleeve, through the sleeve, to the other of the contacts. The other contact may in this case be a moveable contact which can in that case be moved together with the sleeve, while the first contact may be a fixedly arranged contact. In this case too, it will be clear that the distance from the opening to the contact on which the sleeve is mounted will preferably correspond to the so-called predetermined distance, which is advantageously 5 to 105 mm, for example approximately 10 mm to approximately 100 mm.

[0022] In order to ensure successful and rapid discharge of gases which have been contaminated by the arc out of the arc area and to improve this discharge, it is advantageous, according to the invention, if the sleeve is provided with a ventilation system with one or more inlet openings opening out into the contact pas-

sage and one or more outlet openings opening out at the outside of the sleeve, the inlet openings being situated on that side of the opening of the pressure-chamber outlet which is remote from the other of the contacts. It is thus possible to ensure that shortly after the arc has been extinguished, or possibly even while it is being extinguished during the current zero crossing of the arc, contaminated gases are destroyed out of the arc area, in particular out of the contact passage, with the aid of the excess pressure generated by the arc energy. This discharge is of considerable importance, since the gases, i.e. the extinguishing gas, in the contaminated state in fact facilitate/promote the formation of an arc. Moreover, it is possible, in this way, to ensure that extinguishing gas present in the contact passage when connecting the circuit breaker after it has been disconnected is as clean as possible.

[0023] In order to improve the discharge of contaminated gases further, it is advantageous, according to the invention, if the contact passage, at the location of the inlet openings of the ventilation system, widens in the direction away from the other of the contacts.

[0024] In order to improve the discharge of contaminated gases from the contact passage, it is advantageous, according to the invention, if the ventilation system comprises one or more, such as for example two, slots which extend radially outwards from the contact passage and preferably run all the way round the contact passage. Particularly if these slots run all the way round the contact passage, in order in this way to create one or more annular inlet openings of the ventilation system, contaminated gases can be discharged successfully. If slots of this nature are used, the further discharge from the slots is simple to achieve by providing the sleeve with bores which open out onto the slots and, for production engineering reasons, preferably run parallel to the passage, although they may run at an angle with respect to the passage.

[0025] In the case of a power circuit-breaker in which one of the contacts is a preferably fixed contact and the other of the contacts is a moveable contact, it is advantageous, according to a particular embodiment of the invention, if the power circuit-breaker furthermore comprises:

- a fixed piston;
- a drive rod which extends through the fixed piston (19) and bears the moveable contact in order to be able to move it towards and away from the fixed contact; and
- a pressure-chamber cylinder, also known as a puffer cylinder, which is coupled to the drive rod, can be moved together with the drive rod, is arranged on the fixed piston and interacts with the fixed piston and the drive rod so as to form the pressure chamber.

It is thus possible to ensure by relatively simple means that the pressure chamber is pressurized, or pressurized further, by the fixed, at least with respect to the pressure-chamber cylinder, piston as soon as the contacts move away from one another in order to break the contact.

[0026] In order to be able to utilize the energy, in particular heat, released as a result of the arc, it is advantageous, for the purpose of increasing the pressure in the pressure chamber, if a passage system provided with a non-return valve is provided in order for excess pressure formed in the region of the moveable contacts to be able to pass towards the pressure chamber. When closing the contacts, i.e. connecting the circuit-breaker, this non-return valve has the important advantage that it promotes/facilitates sucking fresh gas into the puffer chamber.

[0027] In order to be able to utilize the arc energy, in particular heat and, consequently, increased pressure in the gas, which is released in the vicinity of the arc, it is particularly advantageous, according to the invention, if the fixed piston is mounted on one end of a fixed cylinder, which is open at its other end and through which the drive rod extends, if a piston is mounted on the drive rod so that it can move together with the drive rod, which piston, together with the fixed piston, the drive rod and the fixed cylinder, delimits an intermediate chamber, and if a channel extends through the drive rod, from the moveable contact to the intermediate chamber. In this way, the arc energy which is liberated in the arc area as a result of the arc can be utilized to assist with pulling the contacts (further) apart, due to the fact that the high pressure in the intermediate chamber pushes the moveable piston which can be mounted on the drive rod away from the fixed piston, in the separation direction of the contacts, the open other end of the fixed cylinder ensuring that there is no build-up of pressure therein which might counteract the movement during the movement of the moveable cylinder. Forming at least one passage, which is provided with a non-return valve which allows passage in the direction of the pressure chamber, in the fixed piston on the one hand allows the pressure increase in the arc area caused by the arc energy liberated in that area also to be used to increase the pressure in the pressure chamber, since the non-return valve which allows passage in the direction of the pressure chamber opens when the pressure in the intermediate chamber becomes greater than that in the pressure chamber, and, on the other hand, allows improved flow of fresh gas to the pressure chamber when the contacts are connected.

[0028] According to an advantageous embodiment, the separation of the contacts in the power circuit-breaker according to the invention can be improved further if the moveable piston is provided with at least one passage, which is provided with a non-return valve which allows passage in the direction of the intermediate chamber and runs from the intermediate chamber side towards the opposite side (and prevents flow in the

opposite direction). It is thus possible to prevent the possibility of reduced pressure, which would counteract the separation of the contacts, building up in the intermediate chamber as a result of the moveable piston moving away from the fixed piston. In order to ensure that this non-return valve functions correctly, it is advantageous if it is designed in such a manner that it is open in the contact state, i.e. when the contacts make contact with one another. This ensures that it is not possible for a reduced-pressure situation to arise in the intermediate chamber at the start of the contact-breaking operation. In order, with a non-return valve of this nature, still to be able to utilize additional pressure released as a result of the arc energy, it is advantageous, according to the invention, if the said non-return valve is designed in such a manner that it closes in the event of excess pressure in the intermediate chamber with respect to the area situated on the other side.

[0029] With regard to the power circuit-breaker according to the invention with a so-called intermediate chamber, i.e. the power circuit-breaker according to Claims 21-25, it should be noted that this subject matter, with regard to utilizing the arc energy for driving the contacts apart and/or preventing a reduced pressure in the intermediate chamber and/or increasing the pressure-chamber pressure, can also be used highly advantageously in power circuit breakers from the prior art, which do not provide for a time delay between separating the contacts and subjecting the arc to a gas stream or for a minimum distance between the contacts before the arc is subjected to the gas stream In short, what this means is that the preamble of Claim 19 can therefore be read as "power circuit-breaker, preferably according to one of Claims 8-18, in which one of the contacts is a preferably fixed contact and the other of the contacts is a moveable contact, ...", followed by the characterizing part of Claim 19.

[0030] The present invention will be explained in more detail below with reference to an exemplary embodiment which is diagrammatically depicted in the drawing, in which:

Figure 1 shows a longitudinal section through a power circuit-breaker according to the invention in the connected state, also known as the "on state"
Figure 2 shows a longitudinal section in accordance with that shown in Figure 1, but with the power circuit-breaker in the disconnected stale, also known as the "off state";
Figures 3-6 diagrammatically illustrate the process of breaking the contacts and the phenomena which occur during this process.

[0031] Referring now to Figures 1 and 2, the power circuit-breaker according to the invention, or at least an exemplary embodiment thereof, comprises: a housing 1, 2 and 3 with end parts 1, 3, an insulating cylindrical part 2 and a rod 6 which projects out of the housing at one end and is coupled inside the housing to a hollow drive rod 7 which, at its free end, bears a moveable contact 9. A fixed contact 11 is disposed opposite the moveable contact 9, inside the housing 1, 2, 3. As will be clear, the moveable contact 9, together with the drive rod 7 and pull rod 6, can be pulled, in the direction of arrow V out of the "on state" shown in Figure 1, away from the contact 11 which is fixed with respect to the housing, into the "off state" which is shown in Figure 2 and in which the contact is broken. The contacts 9 and 11 are preferably so-called arcing contacts.

[0032] As can be seen more clearly in particular from Figure 2, the contact 11 essentially comprises an elongate, such as a pin-like, body which is attached to end part 1, on which, in turn, a connection piece for connection to a current or voltage circuit may be provided.

[0033] The housing 1, 2, 3 furthermore accommodates a fixed cylinder 18, specifically in a fixed position with respect to the said housing due to the fact that it is fixed to end part 3, which fixed cylinder 18 in turn bears a fixed piston 19.

[0034] The rod 6 and the hollow drive rod 7 extend through the fixed cylinder 18. At its free end, the hollow drive rod 7 is provided with a flange 20 on which a pressure-chamber cylinder 21, a main sleeve part 22 made from insulating material and a delay sleeve part 23, also made from insulating material, in general the same material as that of the main sleeve part 22, are mounted so that they can move together with the drive rod 7. Main sleeve part 22 and delay sleeve part 23 could be designed so as to form a single unit. Furthermore, the moveable contact 9, which comprises a ring of contact fingers 25, is mounted at the free end of the hollow drive rod 7. The dimensions of the ring of contact fingers 25 and the distance between the fingers are dimensioned in such a manner that the fixed contact pin 11 fits between them, making contact with the fingers all round, by being pushed in between the contact fingers 25.

[0035] A contact passage 26, via which contact 11 can be fitted into sleeve part 22 and sleeve part 23 until it is in contact with the contact fingers 25, and through which contact pin 11 can be pulled out from the contact fingers 25 in the opposite direction, is formed in the main sleeve part 22 and in the delay sleeve part 23.

[0036] Together with the fixed piston 19, drive rod 7 and flange 20, pressure-chamber cylinder 21 delimits a pressure chamber 28, also referred to as pressure area or puffer chamber or puffer area. It will be clear that if drive rod 7 is moved to the left in the direction of arrow V (Figure 1), the volume of pressure chamber 28 falls (cf. also, in this respect, the small volume of pressure chamber 28 in the off state shown in Figure 2), so that the gas which is situated in pressure chamber 28 and, in particular, is an extinguishing gas which is known per se, such as SF_6, is pressurized so that it can be driven towards the contact passage 26, via a pressure-chamber outlet 27 which runs through the insulating sleeve

22, 23 (comprising main sleeve part 22 and delay sleeve part 23), in order, in the contact passage 26, to be able to act on an arc. This assumes that the channel 29 is closed by means of fixed piston 19. This channel 29 will be dealt with in more detail below.

[0037] The method according to the invention for extinguishing an arc, as well as the power circuit-breaker according to the invention which is able to use this method, will now be explained in more detail with reference to the diagrammatic Figures 3, 4, 5 and 6.

[0038] Figure 3 shows a first intermediate position in which the contact has just been broken and an arc 30 has formed between the moving contact fingers 25 and fixed contact pin 11. Due to the energy released in the vicinity of the arc 30, the gas present in the arc area covered by the arc 30, which is preferably an extinguishing gas, such as SF_6, is heated in that area, this increase in temperature on either side of the arc 30 resulting in an increase in pressure. On the inside of the arc, this increase in pressure acts in the direction of arrow 32, towards the left, between the contact fingers 25. As can be seen from Figure 3, in this case the delay sleeve part 23 and the main sleeve part 22, all the way round the annular opening 40 of pressure-chamber outlet 27, adjoin the fixed contact pin 11 which moves with respect to the sleeve 23, 22. This prevents the gas which is present in the pressure chamber 28 and pressure-chamber outlet 27 at elevated pressure from being able to act on the arc 30. Therefore, there is as yet no question of any extinguishing of the arc or of any attempt being made to extinguish the arc. In this case, this extinguishing is deliberately delayed by ensuring that the fixed contact pin 11 and the moving contact fingers 25 have to be pulled apart by a distance d of approximately 15 to 19 mm before contact pin 11 opens the opening 40 of the pressure-chamber outlet 27. It is thus possible to ensure that before any attempt is made to extinguish the arc, on the one hand, the arc 30 is of greater length, making the arc relatively weaker and easier to extinguish, and, on the other hand, at least if the pressure chamber 28 or pressure area 28 arc placed under increased pressure while the contacts are moving apart, the pressure available in the pressure chamber 28 for extinguishing, also known as puffing, is higher or is built up/increased further. The latter effect is intensified still further in particular if the energy and pressure increase generated by the arc 30 and effective in the direction of arrow 32 is utilized, in a manner which is to be described below or optionally in a different manner, to increase the pressure in the pressure chamber 28.

[0039] Figure 4 shows a state which follows Figure 3 and in which the distance between the fixed contact 11 and the moving contact 24, 25 is increased further, and the arc is not, or is not yet, subject to a current zero crossing. In this position, the arc 30, as in the position illustrated in Figure 3, will increase the pressure, on both sides of the arc, of the gas which is situated in the arc area. On the inside of the arc, this pressure increase will still be acting in the direction of arrow 32, between the contact fingers 25, and on the outside of the arc, the pressure increase will be acting in the direction of arrow 33, i.e. directed into the pressure-chamber outlet 27. However, an extinguishing-gas pressure directed as shown by arrow 34 will be acting from the pressure chamber 28 and the pressure-chamber outlet 27, which pressure will be balanced by the arc pressure 33 in the vicinity of a front which is diagrammatically illustrated by line 35. The arc thus prevents a gas stream which would extinguish the arc 30 from moving out of the pressure chamber 28 and the pressure-chamber outlet 27. An extinguishing or puffing action will only be able to take place as soon as the arc 30 becomes weaker as a result of the approach and possibly also passage of a current zero crossing, a position which is illustrated in Figure 5.

[0040] During the approach and possibly also passage of a current zero crossing, the energy of the arc and, consequently, the resultant pressure increase will decrease, so that the pressure 34 from the pressure chamber 28 and pressure-chamber outlet 27 (Figure 4) begins to overcome or over-compensate the pressure 33 generated by the arc energy (Figure 4), with the result that the gas which is present in the pressure chamber 28 and pressure-chamber outlet 27 can actually begin to act on the (weaker) arc in order to extinguish or puff out this arc. The pressure-chamber pressure 34 will initially also be able to escape between the contact fingers 25, at least in the exemplary embodiment illustrated. The distance c between the start of the opening 40 of the pressure-chamber outlet 27, i.e. the end of the delay sleeve part 23, and the point 41 where the contact between the main sleeve part 22 and the fixed contact 11 ends, is in this case preferably selected in such a manner that this distance c approximately corresponds to the distance which is to be covered by the moveable contact, while the contacts arc moving apart, during half an oscillation period (i.e. during a period 1/2f, where f is the frequency in Hz).

[0041] In order to facilitate rapid discharge of gases which have been contaminated by the arc after the arc has been extinguished, the main sleeve part 22 is provided with a ventilation system, the action of which is explained with reference to Figure 6. The ventilation system 42 comprises one or more radial, circular slots 43, the inlet sides of which open out onto a widening section of the contact passage 26. An annular pattern of bores 45 (of which only one is shown), which provides the radial annular slot 43 with outlets which open out at the right-hand end, is arranged in the right-hand end side of the main sleeve part 22.

[0042] Returning to Figures 1 and 2, a further aspect of the invention will be explained in more detail below, which aspect can advantageously be used in combination with the extinguishing delay, but also separately from this delay, in order, in particular, to be able to use the pressure generated by the arc energy as an auxil-

iary force for separating the contacts.

[0043] As can be seen from Figures 1 and 2, a piston 50 which can move together with the drive rod 6 is mounted on the assembly comprising rod 6 and drive rod 7, in particular in the vicinity of the transition between the rod 6 and the drive rod 7. This moveable piston 50 can be moved to and fro through the above-mentioned fixed cylinder 18. The fixed cylinder 18, the fixed piston 19, the drive rod 7 and the moveable piston 50 together delimit the so-called intermediate chamber 51. Via a passage 70 in the wall of the drive rod 7, the interior 71 of the drive rod 7 and passages 53, intermediate chamber 51 is in communication with the area in the vicinity of the contact fingers 25, where the arc may form. Thus, the action of the pressure which is denoted by 32 in Figures 3 and 4 may extend all the way into the intermediate chamber 51. Then, in the intermediate chamber 51, the effect of this pressure 32, which is formed as a result of the arc energy, will be to press the moveable piston 50 away from the fixed piston 19, in the direction of arrow V. Thus, the pressure increase caused by the arc energy can be used to assist with pulling contact fingers 25, on the one hand, and the contact pin 11, on the other hand, (further) apart, at least assuming that the passage 52 in moveable piston 50 is closed off by valve 60, a matter which will be dealt with below.

[0044] If the pressure in the intermediate chamber 51 is greater than the pressure in the pressure chamber 28, gas, via channel 29 and a non-return valve 72 which is arranged therein and allows passage in only one direction, can flow from intermediate chamber 51 into pressure chamber 28, so that the pressure in the pressure chamber 28 is also increased. However, the most important role of valve 72 is to create a closeable pressuring channel, via which, when the contact closes again, the pressure chamber 28 can be filled with fresh gas as a result of the excess pressure which then arises in intermediate chamber 51 compared to that in pressure chamber 28.

[0045] In order to ensure that when moveable piston 50 moves away from the fixed piston 19 in the direction of arrow V it is impossible for any reduced pressure, which could counteract this movement apart, to form in the intermediate chamber 51, a passage 52 with a non-return valve 60 is provided in the moveable piston 50, which non-return valve 60 is able to allow passage in the opposite direction to the arrow V, i.e. in the direction towards the intermediate chamber 51. In order to ensure that this pressure compensation which is used to prevent a reduced pressure in intermediate chamber 51 becomes active as soon as the contacts 25 and 11 begin to move with respect to one another for disconnection purposes, valve 60 is designed in such a manner that it is slightly open in its neutral position, i.e. in the contact state of the contacts. If an excess pressure were to develop in the intermediate chamber 51 as a result of the pressure generated by the arc energy, the valve 60 will close, in order to prevent this pressure from subsiding.

[0046] In order to prevent the possibility of a pressure which could counteract the movement of the piston 50 to the left under the influence of the pressure of the arc energy from being able to build up on the left-hand side of the piston 50, the fixed cylinder 18 is designed to be open at its left-hand end, or is at least provided at this end with a feature allowing flow through the housing. In the exemplary embodiment illustrated in Figure 1 and Figure 2, this is achieved by means of passages 54 in the fixed cylinder 18 which lead towards the interior of the housing 1, 2, 3.

[0047] In the case of the power circuit-breaker according to the embodiment shown in Figures 1 and 2, the contacts can be pulled apart, for example, by means of a preloading mechanism (not shown) which acts on pull rod 6 and, in the "on state" illustrated in Figure 1, is under a prestress which tends to seek to drive the contacts further apart. In general, the stressing mechanism will also be prestressed in the "off state" which is shown in Figure 2.

[0048] For sealing purposes, the pistons 50 and 19 are provided with seals 80, 81.

[0049] The following value, which is determined using the equation from Claims 5 and 12, may be mentioned by way of indication for the distance d. Assuming a system voltage of 72.5 kV, a short-circuit current of 31.5 kA and a value for $a = 1.95 \cdot 10^{-4}$, the equation then gives the value of 17 mm for the distance d.

Claims

1. Method for extinguishing an arc (30) which is formed during the breaking of the electrical contact in a power circuit-breaker, such as a circuit-breaker of the puffer type, by means of a gas stream, such as an SF_6 gas stream, the gas stream coming from a pressure chamber (28) which is placed in connection with the arc (30), and the electrical contact being broken by separating two contacts (11 and 25) from one another and then moving them further apart, characterized in that the connection between the arc (30) and the pressure chamber (28) is brought about:

   - at a predetermined time after the contacts (11 and 25) have been separated from one another and while they are moving further apart; or
   - after the contacts have been separated from one another by a predetermined distance (d).

2. Method according to Claim 1, characterized in that the predetermined time is longer than 1.5 msec, and preferably lies in the range from 1.5 to 15 msec.

3. Method according to one of the preceding claims, characterized in that the speed at which the con-

tacts (11 and 25) move further apart lies at least in the range from approximately 1 to 10 m/sec or higher.

4. Method according to one of the preceding claims, characterized in that the predetermined distance (d) is at least approximately 5 to 105 mm, and preferably lies in the range from approximately 8 mm to approximately 40 mm.

5. Method according to one of the preceding claims, characterized in that the predetermined distance (d) lies in the range which is defined by the equation

$$d = a^3 \cdot U \cdot I,$$

where:

d = the predetermined distance in m
a = constant lying within the range of approximately $1.5 \cdot 10^{-4}$ to approximately $2.6 \cdot 10^{-4}$ with, as the unit

$$\left(\frac{W}{m}\right)^{-\frac{1}{3}}$$

U = the system voltage in V
I = short-circuit current in A to be disconnected.

6. Method according to one of the preceding claims, characterized in that the pressure in the pressure chamber (28) when the contact is broken is built up and/or increased while the contacts (11 and 25) are moving away from one another.

7. Method according to one of the preceding claims, characterized in that the pressure chamber (28) is connected to the arc (30) by moving one (11) of the two contacts which are moving apart past an outflow opening (40) of the pressure chamber (28).

8. Power circuit-breaker of the puffer type, comprising:

- two contacts (11 and 25) which can be separated from one another and moved apart, and between which an arc (30) can be formed in an arc area after the separation and the following movement further apart;
- a pressure chamber (28) which is provided with a pressure-chamber outlet (27) and in which a pressurized gas may be situated during separation of the contacts;

the opening (40) of the pressure-chamber outlet (27) being situated at the edge of the arc area, in such a manner that pressurized gas from the pressure-chamber outlet (27) can act on any arc (30) which may be present, characterized in that the power circuit-breaker furthermore comprises closure means (11, 22, 23) for closing and opening the pressure-chamber outlet (27), which closure means (11, 22, 23) are designed in such a manner that the pressure-chamber outlet (27) is closed at the moment at which the moveable contacts (11 and 25) are separated from one another and is opened:

- at a predetermined time after the contacts (11 and 25) have been separated and while they are moving further apart; or
- after the contacts (11 and 25) have been separated from one another by a predetermined distance (d).

9. Power circuit-breaker according to Claim 8, characterized in that the predetermined time is longer than 1.5 msec, and preferably lies in the range from approximately 1.5 msec to approximately 15 msec.

10. Power circuit-breaker according to Claim 8 or Claim 9, characterized in that it is designed to move the contacts apart at a speed of approximately 1 to 10 m/s or higher.

11. Power circuit-breaker according to one of Claims 8-10, characterized in that the predetermined distance (d) is at least approximately 5 to 105 mm and preferably lies in the range from approximately 8 mm to approximately 40 mm.

12. Power circuit-breaker according to one of Claims 8-11, characterized in that the predetermined distance (d) lies in the range which is defined by the equation

$$d = a^3 \cdot U \cdot I,$$

where:

d = the predetermined distance in m
a = constant lying within the range of approximately $1.5 \cdot 10^{-4}$ to approximately $2.6 \cdot 10^{-4}$ with, as the unit

$$\left(\frac{W}{m}\right)^{-\frac{1}{3}}$$

U = the system voltage in V
I = short-circuit current in A to be disconnected.

13. Power circuit-breaker according to one of Claims 8-12, furthermore comprising a sleeve (22, 23) which is made of insulating material and is provided with a contact passage (26) through which one of the contacts (11) can be moved when they are being sepa-

rated and then moved apart, the pressure-chamber outlet (27) extending through the sleeve (22, 23) so that its opening (40) opens out into the contact passage (26), characterized in that the sleeve (22, 23), all the way round the opening (40), adjoining one (11) of the contacts when this contact is situated in front of the opening (40) so as to form the closure means together with the said one (11) of the contacts.

14. Power circuit-breaker according to Claim 13, characterized in that the sleeve (22, 23) is fixed with respect to the other (25) of the contacts, and in that the contact passage (26) extends from outside the sleeve (22, 23), through the sleeve (22, 23), to as far as the other (25) of the contacts.

15. Power circuit-breaker according to Claim 13 or Claim 14, characterized in that the sleeve (22, 23) is provided with a ventilation system with one or more inlet openings opening out into the contact passage and one or more outlet openings opening out at the outside of the sleeve, the inlet openings being situated on that side of the opening (40) of the pressure-chamber outlet (27) which is remote from the other (25) of the contacts.

16. Power circuit-breaker according to Claim 15, characterized in that the contact passage (26), at the location of the inlet openings of the ventilation system (42), widens in the direction away from the other of the contacts.

17. Power circuit-breaker according to Claim 15 or Claim 16, characterized in that the ventilation system (42) comprises one or more slots (43) which extend radially outwards from the contact passage (26) and preferably run all the way round the contact passage (26).

18. Power circuit-breaker according to Claim 17, characterized in that the ventilation system (42) furthermore comprises one or more bores (45) which preferably run parallel to the passage and open out onto the slots.

19. Power circuit-breaker according to one of Claims 8-18, in which one (11) of the contacts is a preferably fixed contact and the other (25) of the contacts is a moveable contact, characterized in that the power circuit-breaker furthermore comprises:

- a fixed piston (19);
- a drive rod (6, 7) which extends through the fixed piston (19) and bears the moveable contact (25) in order to be able to move it towards and away from the fixed contact (11); and
- a pressure-chamber cylinder (21) which is coupled to the drive rod (6, 7), can be moved together with the drive rod (6, 7), is arranged on the fixed piston (19) and interacts with the fixed piston (19) and the drive rod (6, 7) so as to form the pressure chamber (28).

20. Power circuit-breaker according to Claim 19, characterized in that a passage system (29, 52, 53) provided with a non-return valve is provided in order for excess pressure (32) formed in the region of the moveable contacts (25) to be able to pass towards the pressure chamber (28).

21. Power circuit-breaker according to Claim 19 or Claim 20, characterized in that the fixed piston (19) is mounted on one end of a fixed cylinder (18), which is open at its other end and through which the drive rod (6, 7) extends, in that a moveable piston (50) is mounted on the drive rod (6, 7) so that it can move together with the drive rod, which piston, together with the fixed piston (19), the drive rod (6, 7) and the fixed cylinder (18), delimits an intermediate chamber (51), and in that a channel extends through the drive rod (6, 7), from the moveable contact (25) to the intermediate chamber (51).

22. Power circuit-breaker according to Claim 21, characterized in that at least one passage (29), which is provided with a non-return valve which allows passage in the direction of the pressure chamber (28), is formed in the fixed piston (19).

23. Power circuit-breaker according to Claim 21 or 22, characterized in that the moveable piston (50) is provided with at least one passage (52), which is provided with a non-return valve (53) which allows passage in the direction of the intermediate chamber (51) and runs from the intermediate chamber side towards the opposite side.

24. Power circuit-breaker according to Claim 23, characterized in that the non-return valve (53) is open in the contact state.

25. Power circuit-breaker according to Claim 23 or 24, characterized in that the non-return valve (53), in the event of excess pressure in the intermediate chamber (51), closes with respect to the space lying on the other side.

Fig - 1

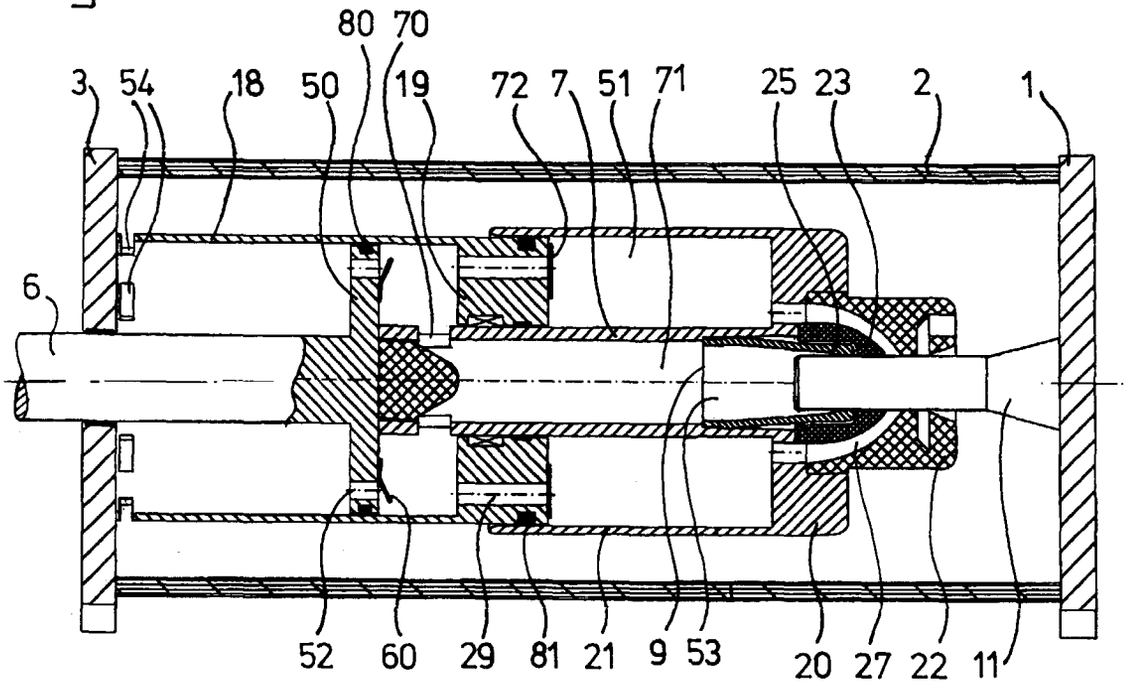
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Fig - 2

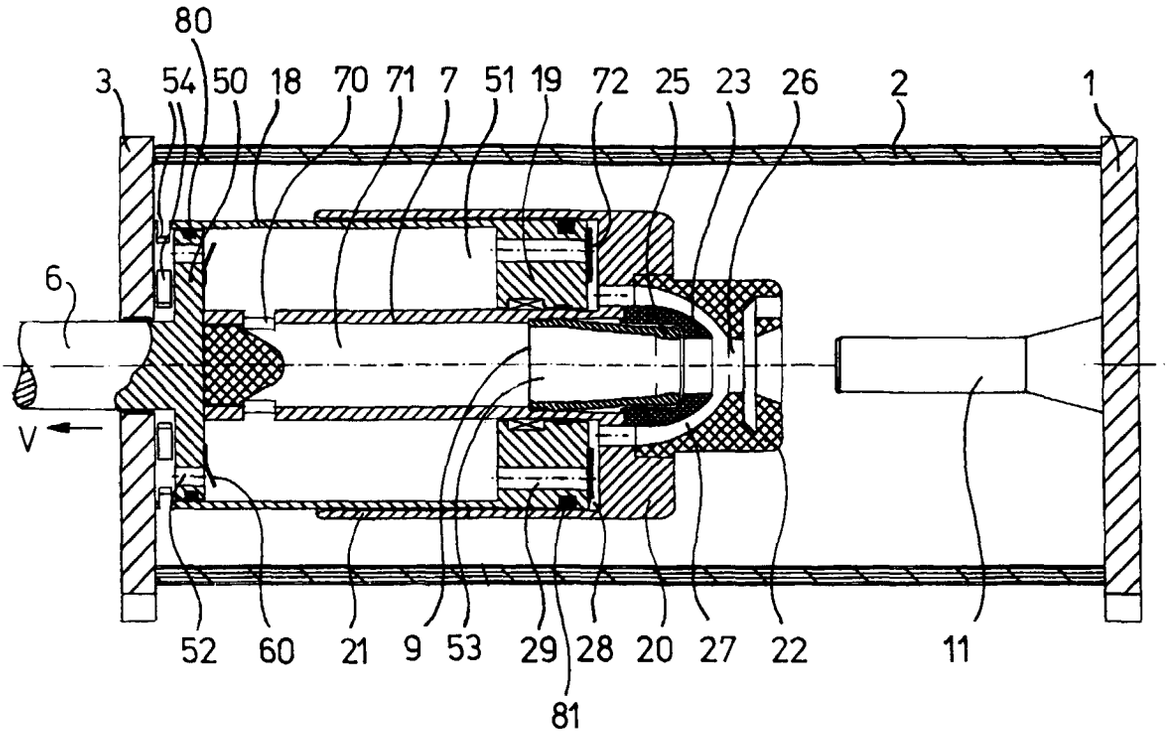
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Fig - 3

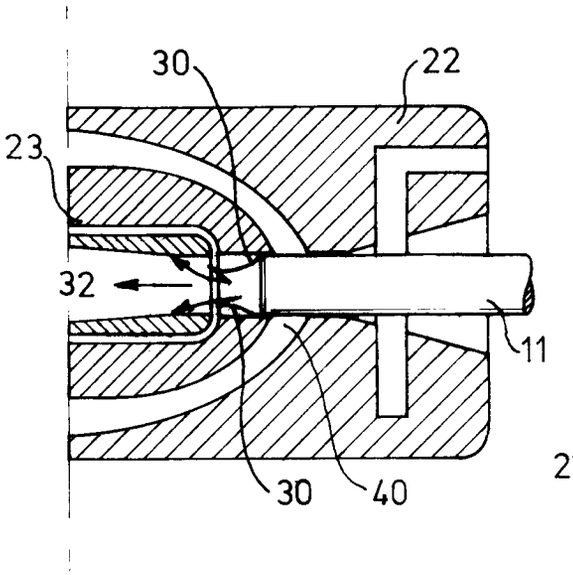


Fig - 4

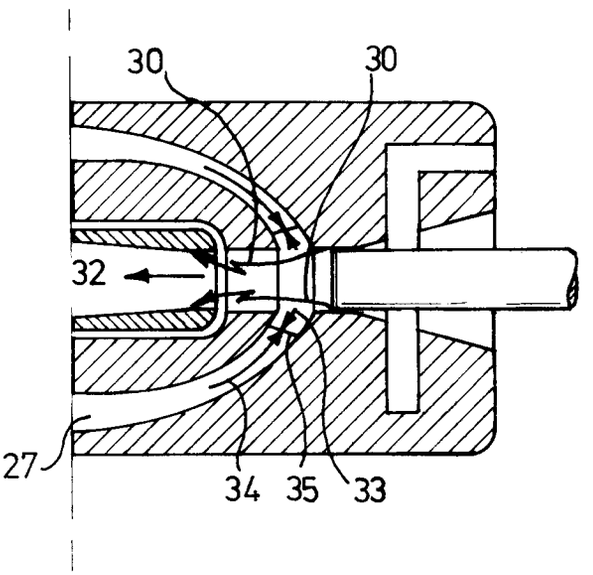


Fig - 5

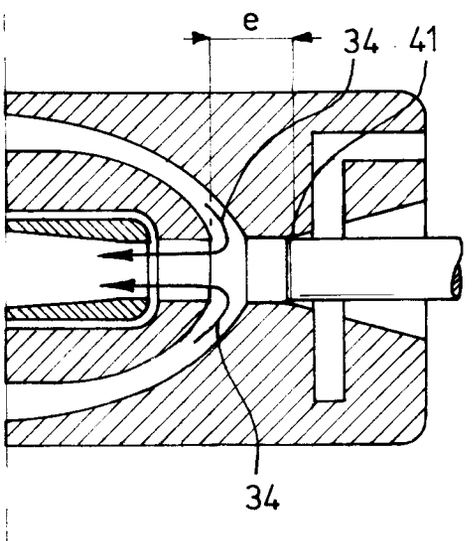
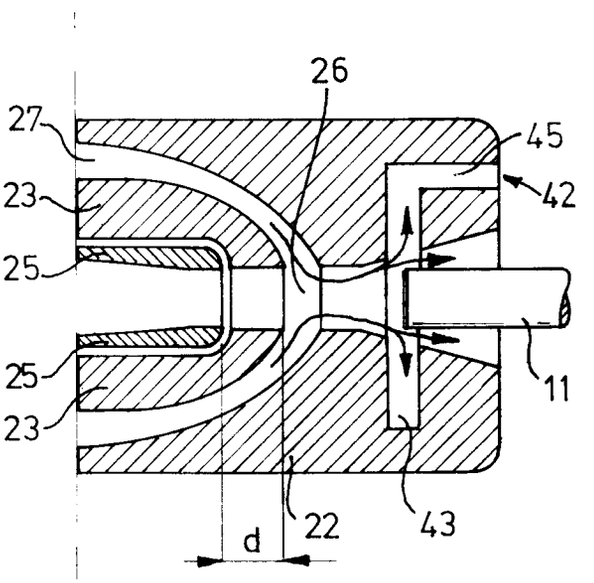


Fig - 6



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 4190

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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D,X	US 3 659 065 A (ROIDT ROBERT MICHAEL ET AL) 25 April 1972 * column 2, line 46-57; figures 3,4 * ---	1,6-8, 13-15	
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TECHNICAL FIELDS SEARCHED (Int.Cl.6)

H01H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22 February 1999	Overdijk, J

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