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(54) **CIRCUIT BREAKER WITH METALLIC ENCLOSURE**

(57) A circuit breaker with metallic enclosure (1) comprises a chamber (3). The chamber comprises a first compartment (31) and a second compartment (32) enclosing an interior volume. The first and second compartments are electrically insulated from each other. A switching actuator (34) is displaceably provided inside at least one of the compartments (31, 32) and configured and adapted to selectively provide electric connection between the compartments. A sealed tank (2) encloses the chamber and is electrically insulated from the chamber, whereby an exterior volume (211) is provided between a wall of the tank and the chamber. The tank and the compartments contain a dielectric gas, and the interior (311, 321) of each compartment of the chamber is fluidly connected to the exterior volume (211) by a flow path having an overall flow cross section. The flow path between the interior volume of each of the compartments and the exterior volume is subdivided into a multitude of ducts, each duct having a partial flow cross section, a hydraulic diameter and a length, wherein the length of each duct is at least twice the hydraulic diameter of the duct.

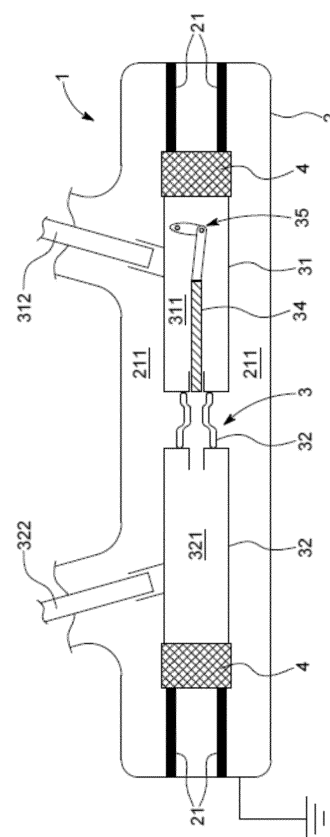


Fig. 1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to a circuit breaker with metallic enclosure as set forth in the claims. It further relates to a method of manufacturing a circuit breaker with metallic enclosure.

BACKGROUND OF THE DISCLOSURE

[0002] Circuit breakers with metallic enclosures generally comprise a chamber connected to the phase and a tank or enclosure enclosing the chamber. Commonly, the tank is electrically connected to the ground and provides a hermetically closed vessel to contain the insulating gas. The chamber is subdivided into two compartments which are electrically insulated from each other. Each compartment is connected to a power line. A switching actuator is provided to selectively make electric contact between the compartments or to open the contact so as to selectively close and open a circuit between the two power lines. The tank is filled with a dielectric gas to cool and quench an arc occurring when switching the circuit. Moreover, unwanted discharge over gaps between components shall be avoided. A gas commonly used in current circuit breaker with metallic enclosures is sulphur hexafluoride, due to the high dielectric withstand. On the other hand, leaking sulphur hexafluoride yields undesirable environmental impacts.

[0003] When the switching actuator opens or closes the circuit, a temporary arc occurs inside the chamber. This arc heats the gas inside the chamber. In embodiments of circuit breaker with metallic enclosures a flow path is provided between the interior of the chamber and an exterior volume between a wall of the tank and the chamber. It has been observed, however, that the hot gases exiting the chamber essentially displace the colder gas in the exterior volume. Mixing between the hot and the colder gases is very poor. Plumes and strains of hot gases thus become present in the space between the chamber and the tank. Those yield a lower dielectric withstand than the colder gas, which increases the propensity for spark-over between the chamber and the tank. Moreover, the hot gas strains or plumes may become present in the space between the chamber and the tank at the time when the peak transient recovery voltage appears after switching. Accordingly, the distance between the tank and the chamber must be sufficiently large to avoid spark-over to the tank even when adverse effects accumulate.

[0004] If it is desired to replace sulphur hexafluoride with other gases which inhibit less environmental hazard, the issue gets even more accentuated. Carbon dioxide, for an instance, already yields a lower dielectric moment. On top, it has a lower molecular weight and lower heat capacity. Thus, the temperature increase due to the energy intake from the switching arc is increased, result-

ing in an even more fierce discharge of heated gas into the space between the chamber and the tank. As a result, the already lower dielectric withstand, when compared to sulphur hexafluoride, is even further reduced, and the chance of hot gas being present at critical locations upon the occurrence of the peak transient recovery voltage is increased. Consequently, under the circumstances outlined, safety against spark-over between the chamber and the tank requires an increase in size. This in turn adds cost, weight, and increases the space requirement.

OUTLINE OF THE SUBJECT MATTER OF THE PRESENT DISCLOSURE

[0005] The present disclosure is related to a circuit breaker with metallic enclosure of the type initially mentioned. In an aspect, the safety and/or the margin against spark-over between the chamber and the tank shall be increased. In aspects, it shall be possible to replace sulphur hexafluoride as the dielectric gas by an environmentally less hazardous gas, without increasing the physical dimensions of the circuit breaker, or, in other aspects, to limit the increase in physical dimensions due to the gas replacement. Said replacement gas may comprise, while not being limited to, carbon dioxide; wherein the carbon dioxide may or may not be combined with dioxide, i.e. molecular O₂, and/or nitrogen, and/or an organofluorine compound selected from the group of a fluoronitrile, a fluoroketone, a fluoroolefine, a fluoroether, an oxirane, a fluoroamine and mixtures and/or by-products of said gases, and further including mixtures of said organofluorine compound with carbon dioxide, ; wherein the carbon dioxide further may or may not be combined with dioxide, i.e. molecular O₂, and/or nitrogen. In another aspect, a circuit breaker with metallic enclosure shall be provided which can be built, independently from the dielectric gas used, as small as possible while providing a sufficient margin against spark-over between the chamber and the tank at a given rated voltage.

[0006] This is achieved by the subject matter described in claim 1.

[0007] Accordingly, disclosed is a circuit breaker with metallic enclosure comprising a chamber. The circuit breaker may in instances be one of dead tank switchgear and a gas insulated switchgear. The chamber comprises a first compartment and a second compartment each having an interior volume, wherein the first and second compartments are electrically insulated from each other. A switching actuator is displaceably provided inside at least one of the compartments and configured and adapted to selectively provide electric connection between the compartments. A sealed tank, which constitutes the enclosure enclosing the circuit breaker, encloses the chamber. The tank is electrically insulated from the chamber, whereby an exterior volume is provided between a wall of the tank and the chamber. Each of the compartments is connected to a line connector penetrating the tank. The penetration opening of each line connector through

the tank is sealed. The line connectors are electrically insulated from the tank. The tank and the compartments contain a dielectric gas. The interior of each compartment of the chamber is fluidly connected to the exterior volume by a flow path having an overall flow cross section. The flow path between the interior volume of each of the compartments and the exterior volume is subdivided into a multitude of ducts, each duct having a partial flow cross section, a hydraulic diameter and a length, wherein the length of each duct is at least twice the hydraulic diameter of the duct. In exemplary embodiments, the length of each duct is at least five times the hydraulic diameter of the duct. In even more specific exemplary embodiments the length of each duct is at least ten times the hydraulic diameter of the duct. In certain embodiments the length of each duct may be one of the aforementioned minimum values or more and 100 or less times the hydraulic diameter of the duct.

[0008] Subdividing the ducts into a multitude of smaller ducts having a relatively long length compared to the flow cross section yields various advantages. On the one hand, a gas blow of heated gas exiting the chamber resulting from an arc inside the chamber has a large contact surface with solid material while escaping from the compartment into the exterior volume, which in turn results in a reduction of the temperature of the escaping gas. The comparatively large gas path length results of a delay of the heated gas exiting into the exterior volume. The heated gas may thus be discharged into the exterior volume only well after the appearance of the peak transient recovery voltage, that is, after the appearance of the peak voltage between the terminals after current interruption. This yields in a lower risk of spark-over between the terminals and spark-over to the tank between the chamber and the tank. An improved mixing between the hot gas emanating from the interior of the chamber and the colder gas in the exterior volume may be achieved, which in turn would yield an improved dielectric withstand of the gas in the exterior volume, again yielding a reduced propensity for spark-over to the tank. Moreover, the reduced gas velocity at the exit into the exterior volume results in reducing the appearance of streaks of unmixed hot gas in the exterior volume, which additionally supports reducing the propensity for spark-over to the tank.

[0009] The synthesis of these benefits allows to use dielectric gases having a lower molecular weight, dielectric withstand and thermal capacity than the quite commonly and widely used sulphur hexafluoride, without the need to increase for instance the distance between the chamber and the tank. Such dimensional increase is highly undesirable as it negatively impacts space requirements, weight and cost. For instance, carbon dioxide may be used to replace sulphur hexafluoride as the dielectric gas inside the tank, despite the fact it has been shown to increase the transient recovery voltage and, by virtue of the lower molecular weight and heat capacity, experiences a larger temperature increase by the switching arc. On the upside, however, the potential environmental im-

pact of carbon dioxide or the above mentioned organofluorine compounds, also in mixture with carbon dioxide, is significantly lower than that of sulphur hexafluoride.

[0010] It might also be possible, alternatively or in addition to expanding the choice of suitable dielectric gases, to reduce the overall dimensions of the circuit breakers, resulting in benefits as to the space requirements, weight and cost.

[0011] Further effects and advantages of the disclosed subject matter, whether explicitly mentioned or not, will become apparent in view of the disclosure provided below.

[0012] It is noted that within the framework of the present disclosure the use of the indefinite article "a" or "an" does in no way stipulate a singularity nor does it exclude the presence of a multitude of the named member or feature. It is thus to be read in the sense of "at least one" or "one or a multitude of".

[0013] It may be provided that the chamber comprises two compartments which are coaxially arranged adjacent each other. Each compartment may, under these circumstances, have a free axial end on which the ducts for providing fluid communication between the interior volume of the respective compartment and the exterior volume is provided. The switching actuator may be a rod with a longitudinal axis extending parallel to the axes of the compartments. The rod may be arranged coaxially with the compartments. The rod may be contained inside at least one of the compartments and may be axially displaceable along a longitudinal axis of the rod or the axes of the compartments, respectively.

[0014] In more specific embodiments of the herein disclosed circuit breaker with metallic enclosure at least one duct extends from an inlet adjacent the interior volume of a compartment to an outlet adjacent the exterior volume, wherein further a lateral fluid connection between the duct and the exterior volume is provided and joins the duct between the inlet and the outlet. While hot gases flow through the duct from inside the chamber, or compartment, respectively, colder gas from the exterior volume may thus be entrained through the lateral fluid connection. This embodiment fosters a mixing of the hot gas flowing from inside the chamber, or compartment, respectively, with colder gas from the exterior volume, resulting in a temperature reduction of the gases discharged through the duct and into the exterior volume. Thus, any strains or bubbles of discharged gas eventually forming in the exterior volume will be less prone to cause spark-over to the tank as the detrimental effect on the dielectric withstand is reduced. This may be achieved in that, in embodiments, at least one duct comprises a lateral opening in the duct wall.

[0015] In embodiments, the fluid communication between the interior volume of a compartment and the exterior volume may be provided by a bundle of tube-shaped ducts.

[0016] In aspects, at least one duct may be at least one of curved and/or spiraled. In such embodiments, the

length of a duct may be significantly enlarged when compared to an overall dimension of the duct, i.e. a linear distance between the inlet and the outlet of a duct. The contact surface between the gases flowing through a duct and the walls of the duct is consequently enlarged, increasing the heat exchange between the gases and the walls. Also, a curved and/or spiraling flow path may per se yield a more intense heat exchange with the walls compared to a straight flow path. Consequently, providing a curved and/or spiraled duct supports reducing the temperature of the gas discharged into the exterior volume. As a further effect, the increase of the overall flow path length results in a delay of the discharge of the gases caused by the switching arc. Accordingly, the hot gases with the unwanted reduction of dielectric withstand may reach critical locations only well after the appearance of the peak transient recovery voltage.

[0017] In non-limiting exemplary embodiments of the herein described circuit breaker with metallic enclosure at least one duct is nozzle-shaped with the partial flow cross section tapering from an upstream end to a downstream end in a direction from the interior of the compartment to the exterior volume. In more particular embodiments a downstream end of a first nozzle may be arranged to discharge into an upstream end of a downstream duct, wherein further more in particular the upstream end of the downstream duct may be in fluid communication with the exterior volume. The downstream duct may be provided as a second nozzle, which in particular tapers from the upstream end to a downstream end. These embodiments yield an ejector type arrangement, wherein the high momentum fluid discharged from the first nozzle served to entrain fluid from the exterior volume, which is mixed with the fluid discharged from the first nozzle in the downstream duct. Thus, hot gas from inside the chamber flowing through the first nozzle is effectively cooled through mixing with colder gas before being discharged into the exterior volume. Two or more of the aforementioned ejector arrangements may be arranged serially.

[0018] The ducts may in particular embodiments be manufactured by additive manufacturing methods. This allows for more complex geometries and stronger convoluted ducts than machining the ducts, while cost is significantly reduced when compared to assembling the ducts from individual members.

[0019] In further aspects of the present disclosure, the chamber may comprise two axial ends, wherein at least one axial end is provided with an end cap and further the ducts are provided in the end cap. More in particular, the chamber may be axially divided into the two compartments, such that each axial end of the chamber is an axial end of one of the compartments. As such, it may be provided that each compartment comprises a central end adjacent the other compartment and a free end which at the same time constitutes an axial end of the chamber. Said free end may consequently, in embodiments, be provided with the end cap as mentioned above. It is un-

derstood that the end cap may be a separate member from the chamber and may be affixed to an axial end of the chamber. The ducts may be provided by fixtures inside the end cap.

[0020] In further embodiments a circumferential wall of the end cap is provided with openings so as to provide a fluid communication between the exterior volume and at least one of the ducts.

[0021] The end caps, and in particular the fixtures inside the end cap which define the ducts may be additively manufactured members, yielding essentially the benefits as outlined above in connection with additively manufactured ducts.

[0022] In particular embodiments of the herein disclosed subject matter the tank is grounded, that is electrically connected to the ground.

[0023] The dielectric gas contained inside the tank and the chamber may be carbon dioxide, wherein the carbon dioxide further may or may not be combined with dioxide, i.e. molecular O₂, and/or nitrogen, and/or an organofluorine compound selected from the group of a fluoronitrile, a fluoroketone, a fluoroolefine, a fluoroether, an oxirane, a fluoroamine and mixtures and/or by-products of said gases, and further including mixtures of said organofluorine compound with carbon dioxide wherein the carbon dioxide further may or may not be combined with dioxide, i.e. molecular O₂, and/or nitrogen.

[0024] Further disclosed is a method of manufacturing a circuit breaker with metallic enclosure of the kind disclosed above. The method comprises providing a chamber. The chamber is divided into two compartments electrically insulated from each other. A displaceable switching actuator is provided inside at least one of the compartments. The switching actuator is configured and adapted to selectively make electric contact between the first and second compartments. The method comprises providing a tank enclosing the chamber and providing a fluid communication between an interior volume of the chamber and an exterior volume defined between a wall of the tank and the chamber. Further, the tank is filled with a dielectric gas. Providing the fluid communication between the interior volume of the chamber and the exterior volume defined between a wall of the tank comprises providing a multitude of ducts. Providing the multitude of ducts comprises manufacturing the multitude of ducts by an additive manufacturing method. It is further understood that providing the ducts may comprise providing at least one end cap comprising the ducts, wherein providing the end cap comprises manufacturing the end cap by an additive manufacturing method. Providing the end cap may in particular comprise attaching the end cap to an axial end of the chamber. More in particular, an end cap may be attached to each axial end of the chamber.

[0025] In still further aspects a method of operating a circuit breaker with metallic enclosure is disclosed. The circuit breaker comprises a chamber enclosing an interior volume and comprising a first compartment and a second compartment. The first and second compartments en-

close the interior volume. The first and second compartments are electrically insulated from each other. A switching actuator is provided inside at least one of the compartments and configured and adapted to selectively provide electric connection between the compartments. A sealed tank encloses the chamber and is electrically insulated from the chamber, whereby an exterior volume is provided between a wall of the tank and the chamber. Each of the compartments is connected to a line connector penetrating the tank, wherein the penetration opening of each line connector through the tank is sealed and the line connectors are electrically insulated from the tank. The tank and the compartments contain a dielectric gas and the interior volume of each compartment of the chamber is fluidly connected to the exterior volume. The method comprises one of establishing and interrupting electric contact between the first and second compartments, thereby inducing an arc, whereby the arc heats the gas inside the interior volume and discharging the thus heated gas into the exterior volume.

[0026] In a first embodiment of said method the method comprises diffusing the stream of heated gas discharged from the interior volume to the exterior volume prior to releasing the heated gas into the exterior volume. Diffusing, in this respect, shall be understood as splitting the entire stream of heated gas to be discharged up into a multitude of partial streams which, upon entry into the exterior volume, get better dissipated and admixed in the relatively cooler gas in the exterior volume, thus avoiding the formation of plumes or strains of the heated gas in the exterior volume, that is, between the compartments and the tank. The multitude of partial streams may count at least 10, at least 15, at least 25 or at least 40. The multitude of partial streams may count one of the aforementioned minimum values or more and 1000 or less.

[0027] In a second embodiment of said method the method comprises admixing the heated gas which is discharged with gas from the exterior volume prior to releasing the heated gas into the exterior volume. Thus, the temperature of the gas, upon being released into the exterior volume, is significantly reduced when compared to the temperature of the heated gas inside the interior volume.

[0028] In a third embodiment of said method the method comprises directing the heated gas which is discharged through a multitude of ducts and cooling the heated gas which is discharged while flowing through the multitude of ducts in exchanging heat with the duct walls. In particular the length of each duct may be at least twice the hydraulic diameter of the duct. In more particular embodiments, the length of each duct may be at least five times the hydraulic diameter of the duct. In even more specific exemplary embodiments the length of each duct may be at least ten times the hydraulic diameter of the duct. In certain embodiments the length of each duct may be one of the aforementioned minimum values or more and 100 or less times the hydraulic diameter of the duct. The multitude of ducts may count at least 10, at least 15,

at least 25 or at least 40. The multitude of ducts may count one of the aforementioned minimum values or more and 1000 or less.

[0029] In a method of operating a circuit breaker with metallic enclosure as set forth above the method steps of the above-described first through third embodiments may be combined with each other. The circuit breaker may, while not limited to, be an embodiment of a circuit breaker as herein described.

[0030] It is understood that the features and embodiments disclosed above may be combined with each other. It will further be appreciated that further embodiments are conceivable within the scope of the present disclosure and the claimed subject matter which are obvious and apparent to the skilled person.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The subject matter of the present disclosure is now to be explained in more detail by means of selected exemplary embodiments shown in the accompanying drawings. The figures show

- Fig. 1 an exemplary embodiment of a circuit breaker with metallic enclosure;
- Fig. 2 a first exemplary embodiment of providing fluid communication between the interior volume of a compartment and the exterior volume enclosed between the chamber and the wall of the tank;
- Fig. 3 a second exemplary embodiment of providing fluid communication between the interior volume of a compartment and the exterior volume enclosed between the chamber and the wall of the tank;
- Fig. 4 a further exemplary embodiment of providing fluid communication between the interior volume of a compartment and the exterior volume enclosed between the chamber and the wall of the tank; and
- Fig. 5 still a further exemplary embodiment of providing fluid communication between the interior volume of a compartment and the exterior volume enclosed between the chamber and the wall of the tank;

[0032] It is understood that the drawings are highly schematic, and details not required for appreciating the disclosed subject matter may have been omitted for the ease of understanding and depiction. It is further understood that the drawings show only selected, illustrative embodiments, and embodiments not shown may still be well within the scope of the herein disclosed and/or claimed subject matter.

EXEMPLARY MODES OF CARRYING OUT THE TEACHING OF THE PRESENT DISCLOSURE

[0033] Figure 1 shows an exemplary embodiment of a circuit breaker with metallic enclosure 1 according to the present disclosure. Circuit breaker 1 comprises a tank 2 and a chamber 3 enclosed by the tank. The tank commonly is grounded. Chamber 3 is supported inside tank 2 by insulating supports 21 and surrounded by an exterior volume 211. Chamber 3 comprises a first compartment 31 and a second compartment 32 which are disposed along a common axis. Each compartment is connected to a line connector 312, 322. The line connectors extend through the wall of the tank 2, whereas the openings through which the line connectors extend are sealed so as to maintain a gas inside tank 2. The line connectors are insulated from the tank. Each compartment 31, 32 encloses an interior volume 311, 321, commonly forming an interior volume of the chamber. As will be outlined below in more detail, the interior volume 311, 321 is fluidly connected to the exterior volume 211. An insulator member 33 is provided axially between compartments 31 and 32 so as to electrically insulate compartments 31, 32 from each other. An axial passageway is centrally provided through insulator member 33. Inside one of the compartments a switching actuator 34 is provided. Switching actuator 34 is a rod which is axially displaceable. Switching actuator 34 and the central passageway of insulator member 33 are adapted to each other so as to allow switching actuator 34 to advance through the central passageway. Thus, switching actuator 34 is enabled to selectively close and open and electric contact between the compartments. An actuation mechanism 35 is provided to effect displacement of switching actuator 34. End caps 4 are provided on the axial ends of chamber 3. In each end cap 4 a multitude of ducts are provided which establish fluid communication between the interior volume 311, 321 of the compartments and the exterior volume 211. As noted, compartments 31, 32 are connected to line voltage, while tank 2 is grounded. It is important that spark-over between the tank and the compartments is avoided. To this extent the tank is filled with a dielectric gas, and the distance between the walls of the tank and the compartments is chosen sufficiently large that, in further consideration of the dielectric properties of the gas, spark-over is avoided in minimum at a rated voltage. The gas contained within the interior volume 311, 321 of the compartments in addition has a further function. When the switching actuator opens or closes the electric contact between the compartments, a switching arc appears between switching actuator 34 and the second compartment 32. The gas is intended to cool and quench the switching arc. Due to energy intake from the switching arc the gas inside the compartments heats up and expands. In the gas is displaced through the ducts in the end caps and into the exterior volume. Through the temperature increase the dielectric withstand of the gas is reduced. Thus, in the presence of heated gas spark-over

may occur under conditions under which it would not in the presence of gas of a lower temperature. Moreover, upon switching a transient increase of voltage is observed, the so-called transient recovery voltage, which further increases the risk of spark-over between the chamber and the tank, in particular if strains of heated gas become present in the exterior volume 211 between the chamber and the wall of the tank. This requires to provide a considerable margin against spark-over, which means, for a given rated voltage and specific dielectric properties of the gas inside the tank, that the distance between the chamber and the wall of the tank must be oversized. Said problem may further be the more accentuated the lower the molecular weight and heat capacity of the dielectric gas is. For instance, carbon dioxide yields a significantly lower molecular weight and heat capacity than sulphur hexafluoride. That means, upon a certain energy intake from the switching arc, temperature increase of the gas is higher, and moreover the velocity at which the heated gas is discharged from the interior volume 311, 321 into the exterior volume 211 is increased. This, on the one hand, increases the likelihood of strains or plumes of heated gas being present in the exterior volume, and further the likelihood of strains or plumes of heated gas being present in the exterior volume at the time of the appearance of the peak transient recovery voltage. Adding margin against spark-over in increasing the distance between the wall of the tank and interior components being connected to line voltage increases the space requirement of the circuit breaker, adds weight, and adds cost. Thus, according to the present disclosure, the fluid communication between the interior volume 311, 321 and the exterior volume 211 is provided by a multitude of ducts having a length which exceeds the hydraulic diameter. Thus, the discharge of heated gas from the interior volume to the exterior volume may be delayed so that hot gas may reach critical locations only well after the occurrence of the peak transient recovery voltage. Further, due to providing an increased surface between the flow of heated gas and the material of the duct walls, significant amounts of heat are transferred from the gas to the solid material. Hence, the heated gas is significantly cooled down upon being discharged through the ducts, and the degradation of dielectric withstand is significantly reduced. In another aspect, it may be achieved that the heated gas, upon exiting the compartments, is admixed with gas from the exterior volume, and the propensity of strains or plumes of hot gas occurring is reduced. It may further be beneficial if the flow of gas discharged into the exterior volume is directed away from the circumferential space between the circumferential surface of the chamber, or the compartments, respectively, and the wall of the tank. The propensity for spark-over to the tank is thus largely reduced for a given combination of circuit breaker size, line voltage and dielectric gas. For a given combination of rated voltage and dielectric gas, the size of the circuit breaker can be reduced while maintaining the margin against spark-over to the tank. This reduces space

requirement, weight and cost.

[0034] Non-limiting exemplary embodiments of the ducts for discharging the heated gas from inside the compartments to the exterior volume are disclosed in figures 2 - 5. Figure 2 shows a compartment 31 of a circuit breaker with an end cap 4. End cap 4 includes a multitude of blades 41. The blades 41 subdivide the total flow cross-section provided inside end cap 4 into a multitude of ducts between blades 41. The blades are shaped so as to impose a swirling movement on the gases discharged from the interior 311 of compartment 31. The gases are discharged on a front face and a circumferential surface of end cap 4. The axial velocity component of the gases exiting into the exterior volume 211 is directed away from the compartment. The blades 41 provided in the end cap provided a large heat exchange surface with the gas flowing through the ducts, which serves to reduce the temperature of the heated gas being discharged from the interior volume 311 to the exterior volume 211. Moreover, due to the non-linear, curved flow path inside end cap 4 the delay time from the occurrence of the switching arc until the heated gas actually enters the exterior volume 211 is comparatively large. Accordingly, the actual discharge of the heated gas into the exterior volume may be delayed until well after the time of occurrence of the peak transient recovery voltage. In addition, the swirl imposed on the discharged heated gas may cause a mixing with non-heated gas from the exterior volume and may thus serve to avoid or at least reduce the occurrence of strains or plumes of heated gas in the exterior volume.

[0035] In a further embodiment shown in figure 3 the ducts inside the end cap 4 are provided by chicane-shaped fixtures 42. The flow inside these ducts includes return flows which intensify heat transfer from the gas to the fixtures. Moreover, low-pressure dead wakes may serve to ingest non-heated gas from the exterior volume through openings in the circumferential surface of the end cap, which intensely mixes with the heated gas. The temperature of the heated gas may thus be largely reduced before being discharged into the exterior volume 211. As with the embodiment of figure 2, the delay time from the occurrence of the switching arc until the heated gas actually enters the exterior volume 211 is comparatively large. Accordingly, the actual discharge of the heated gas into the exterior volume may be delayed until well after the time of occurrence of the peak transient recovery voltage. The gas discharged from the interior volume 311 is discharged into the exterior volume in a direction away from the chamber, or the compartments, respectively.

[0036] According to an embodiment outlined in figure 4, the end cap comprises a multitude of tube-shaped ducts 43 arranged in a bundle adjacent to each other. The tube-shaped ducts may in particular embodiments exhibit honeycomb shaped cross sections. The tube-shaped ducts have lateral openings which fluidly interconnect the ducts with each other and with the exterior volume 211. The gas flowing through the ducts may thus ingest non-heated gas from the exterior volume, thus re-

ducing the temperature of the gas discharged into the exterior volume at a downstream end of the ducts. Also in this embodiment, the large surface/volume ratio of the ducts results in an intense heat exchange between the gas and the walls of the ducts, which serves to reduce the temperature of the gas flowing through the ducts. Depending on the length of the ducts the actual discharge of the heated gas into the exterior volume may be delayed until well after the occurrence of the peak transient recovery voltage. The gas discharged from the interior volume is discharged into the exterior volume in a direction away from the chamber, or the compartments, respectively.

[0037] In an exemplary embodiment shown in figure 5 the ducts through which the heated gas is discharged from the interior volume 311 to the exterior volume 211 is provided by nozzles 44 tapering from an upstream end to a downstream end in a direction from the interior of the compartment to the exterior volume. The ducts comprise lateral openings in that downstream of each nozzle an ingestion flow path is provided in fluid communication with the exterior volume 211 on a circumferential surface of the end cap 4. Hence, the fluid discharged from a nozzle 44 provides a motive force to ingest non-heated gas from the exterior volume 211 into the ducts, thus mixing the heated gas from the interior volume 311 with non-heated gas from exterior volume 211. The nozzles thus work as ejectors. The temperature of the discharged gas is thus reduced. As can be seen, nozzles are arranged to discharge into an upstream end of a downstream duct, whereas the upstream end of the downstream duct is in fluid communication with the exterior volume. In embodiments, a downstream duct may also be nozzle-shaped, thus providing for a serial ejector arrangement. The temperature of the gas discharged from the interior volume 311 is accordingly reduced by heat exchange with the walls of the nozzles and further through ingestion of and mixing with non-heated gas from the exterior volume 211. The overall length of the flow path provided may, as outlined above, again result in a delayed discharge of gas from the interior volume into the exterior volume, wherein the actual discharge of the heated gas into the exterior volume may be delayed until well after the occurrence of the peak transient recovery voltage. The gas discharged from the interior volume 311 is discharged into the exterior volume in a direction away from the chamber, or the compartments, respectively.

[0038] While the subject matter of the disclosure has been explained by means of exemplary embodiments, it is understood that these are in no way intended to limit the scope of the claimed invention. It will be appreciated that the claims cover embodiments not explicitly shown or disclosed herein, and embodiments deviating from those disclosed in the exemplary modes of carrying out the teaching of the present disclosure will still be covered by the claims.

Claims

1. A circuit breaker with metallic enclosure (1) comprising a chamber (3), the chamber enclosing an interior volume (311, 312) and the chamber comprising a first compartment (31) and a second compartment (32), wherein the first and second compartments enclose the interior volume and wherein the first and second compartments are electrically insulated from each other,
a switching actuator (34) displaceably provided inside at least one of the compartments (31, 32) and configured and adapted to selectively provide electric connection between the compartments, and
a sealed tank (2) enclosing the chamber and electrically insulated from the chamber, whereby an exterior volume (211) is provided between a wall of the tank and the chamber,
wherein each of the compartments is connected to a line connector (312, 322) penetrating the tank, wherein the penetration opening of each line connector through the tank is sealed and the line connectors are electrically insulated from the tank,
wherein the tank and the compartments contain a dielectric gas and the interior volume (311, 321) of each compartment of the chamber is fluidly connected to the exterior volume (211) by a flow path having an overall flow cross section,
characterized in that the flow path between the interior volume of each of the compartments and the exterior volume is subdivided into a multitude of ducts, each duct having a partial flow cross section, a hydraulic diameter and a length, wherein the length of each duct is at least twice the hydraulic diameter of the duct.
2. The circuit breaker with metallic enclosure (1) according to the preceding claim, wherein at least one duct extends from an inlet adjacent the interior volume (311, 321) of a compartment (31, 32) to an outlet adjacent the exterior volume (211), and wherein further a lateral fluid connection between the duct and the exterior volume is provided and joins the duct between the inlet and the outlet.
3. The circuit breaker with metallic enclosure according to the preceding claim, wherein at least one duct comprises a lateral opening in the duct wall.
4. The circuit breaker with metallic enclosure according to any preceding claim, wherein the fluid communication between the interior volume (311, 321) of a compartment (31, 32) and the exterior volume (211) is provided by a bundle of tube-shaped ducts (43).
5. The circuit breaker with metallic enclosure according to any preceding claim, wherein at least one duct is curved.
6. The circuit breaker with metallic enclosure according to any of the preceding claims, wherein at least one duct is spiraled.
7. The circuit breaker with metallic enclosure according to any of the preceding claims, wherein at least one duct (44) is nozzle-shaped with the partial flow cross section tapering from an upstream end to a downstream end in a direction from the interior (311, 321) of the compartment to the exterior volume (211).
8. The circuit breaker with metallic enclosure according to the preceding claim, wherein a downstream end of a first nozzle is arranged to discharge into an upstream end of a downstream duct, and further the upstream end of the downstream duct is in fluid communication with the exterior volume (211).
9. The circuit breaker with metallic enclosure according to any of the preceding claims, wherein the chamber (3) comprises two axial ends, wherein at least one axial end is provided with an end cap (4), wherein the ducts are provided in the end cap.
10. The circuit breaker with metallic enclosure according to the preceding claim, wherein the ducts are provided by fixtures (41, 42, 43, 44) inside the end cap (4).
11. The circuit breaker with metallic enclosure according to the preceding claim, wherein a circumferential wall of the end cap (4) is provided with openings so as to provide a fluid communication between the exterior volume and at least one of the ducts.
12. A method of manufacturing a circuit breaker with metallic enclosure according to any of the preceding claims, comprising
providing a chamber (3) wherein the chamber is divided into two compartments (31, 32) electrically insulated from each other,
providing a displaceable switching actuator (34) inside at least one of the compartments which is configured and adapted to selectively make electric contact between the compartments,
providing a tank (2) enclosing the chamber (3),
providing a fluid communication between an interior volume (311, 321) of the chamber and an exterior volume (211) defined between a wall of the tank and the chamber, and
filling the tank (2) with a dielectric gas,
characterized in that providing the fluid communication between the interior volume (311, 321) of the chamber and the exterior volume (211) defined between the chamber (3) and the wall of the tank (2) comprises providing a multitude of ducts, wherein providing the multitude of ducts comprises manufacturing the multitude of ducts by an additive manufacturing

turing method.

13. A method of operating a circuit breaker with metallic enclosure, the circuit breaker comprising a chamber (3), the chamber enclosing an interior volume (311, 312) and the chamber comprising a first compartment (31) and a second compartment (32), wherein the first and second compartments enclose the interior volume and wherein the first and second compartments are electrically insulated from each other, a switching actuator (34) provided inside at least one of the compartments (31, 32) and configured and adapted to selectively provide electric connection between the compartments, and a sealed tank (2) enclosing the chamber and electrically insulated from the chamber, whereby an exterior volume (211) is provided between a wall of the tank and the chamber, wherein each of the compartments is connected to a line connector (312, 322) penetrating the tank, wherein the penetration opening of each line connector through the tank is sealed and the line connectors are electrically insulated from the tank, wherein the tank and the compartments contain a dielectric gas and the interior (311, 321) of each compartment of the chamber is fluidly connected to the exterior volume (211), the method comprising one of establishing and interrupting electric contact between the first and second compartments, thereby inducing an arc, whereby the arc heats the gas inside the interior volume, and discharging the thus heated gas into the exterior volume, **characterized in that** discharging the heated gas into the exterior volume comprises diffusing the heated gas which is discharged from the interior volume to the exterior volume prior to releasing it into the exterior volume.
14. The method of the preceding claim, **characterized in** admixing the heated gas which is discharged with gas from the exterior volume prior to releasing the heated gas into the exterior volume.
15. The method of any of the two preceding claims **characterized in** directing the heated gas which is discharged through a multitude of ducts, and cooling the heated gas which is discharged while flowing through the multitude of ducts in exchanging heat with the duct walls, wherein in particular the length of each duct is at least twice the hydraulic diameter of the duct.

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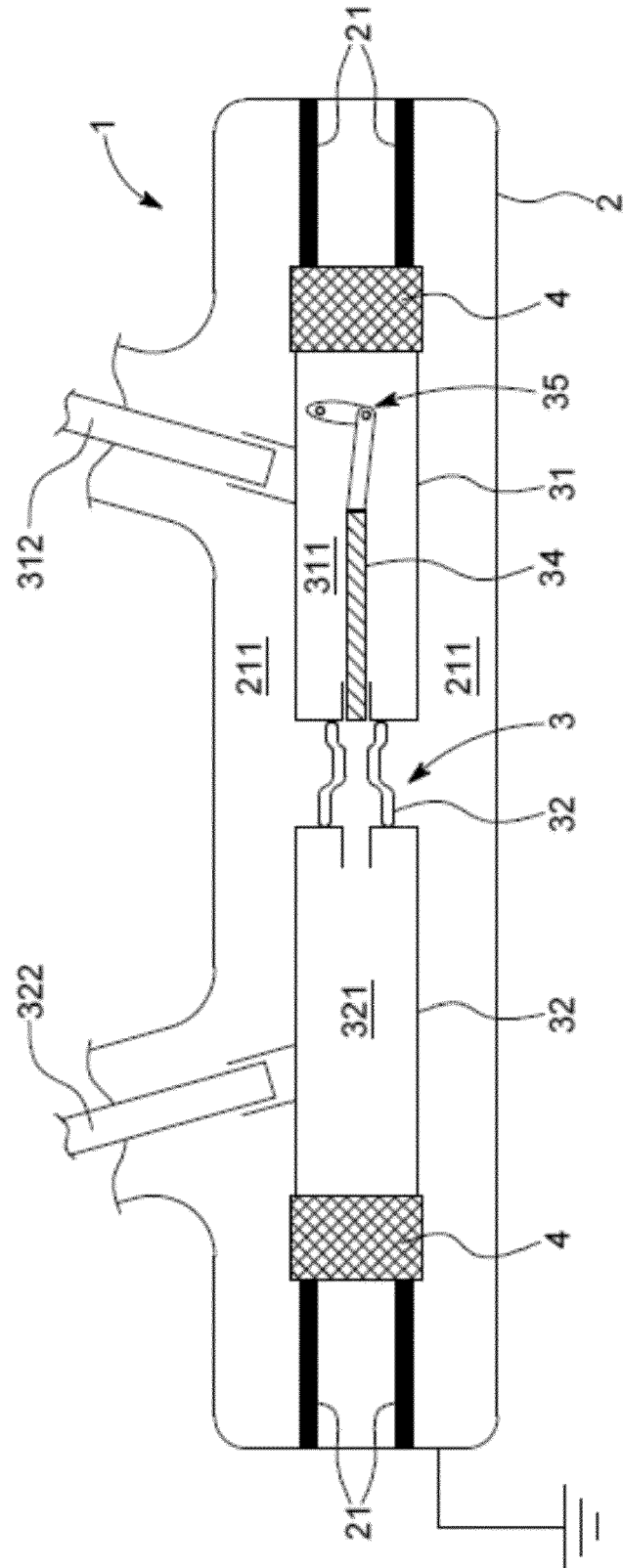
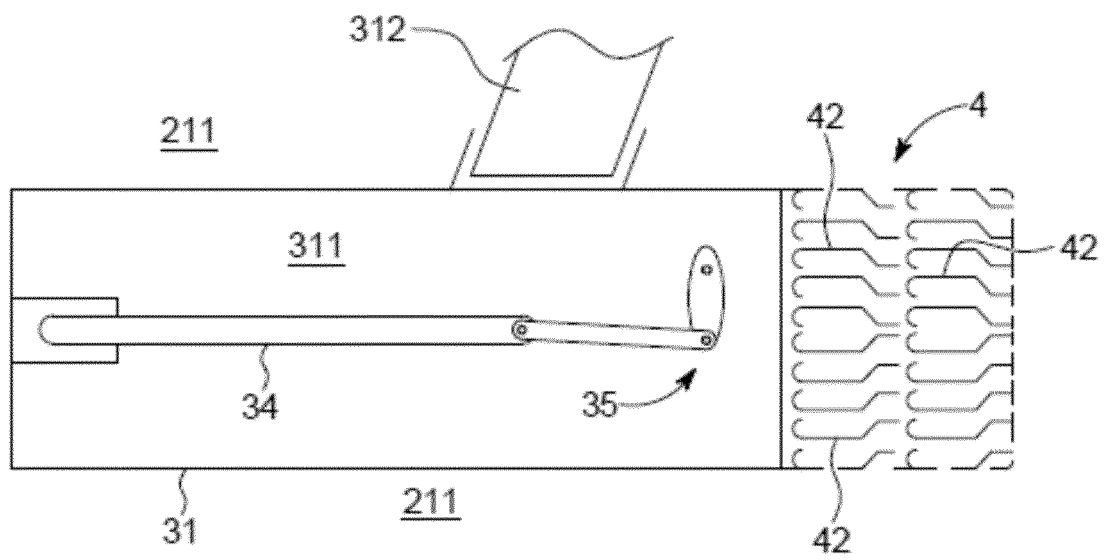
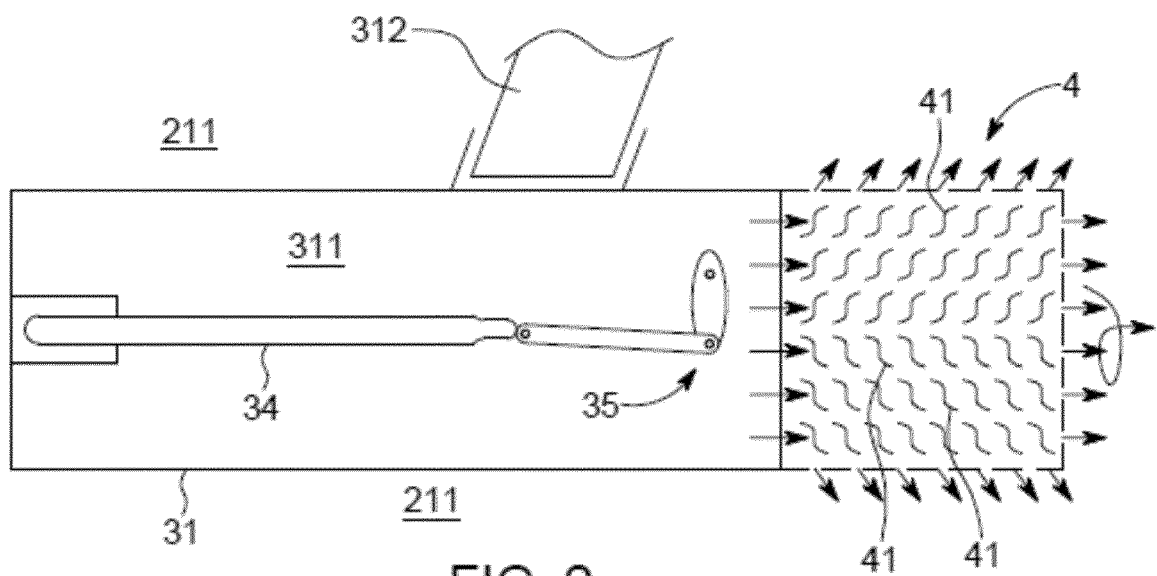


Fig. 1



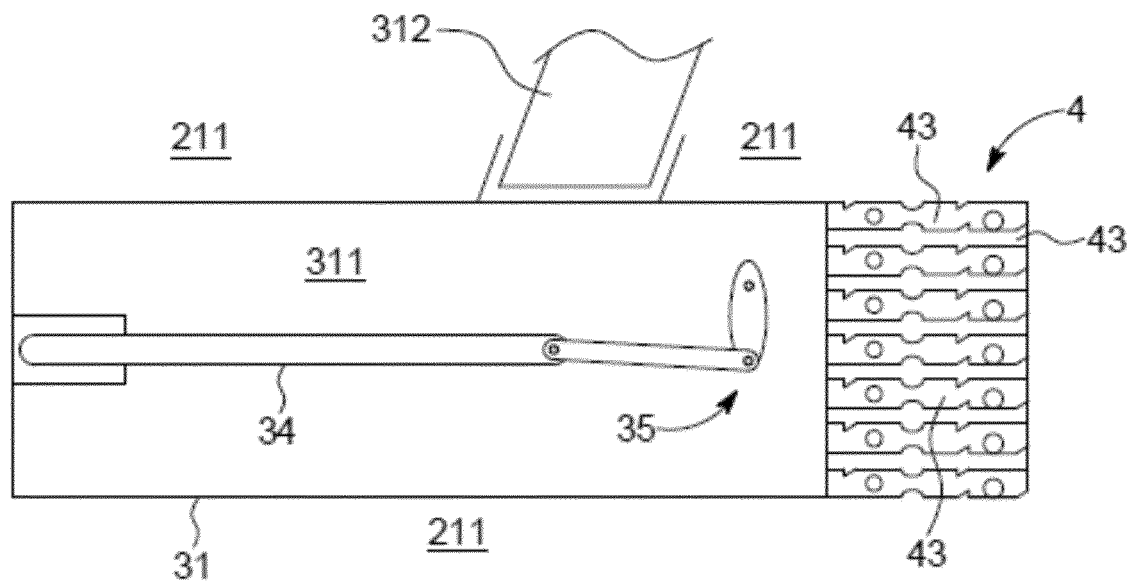


FIG. 4

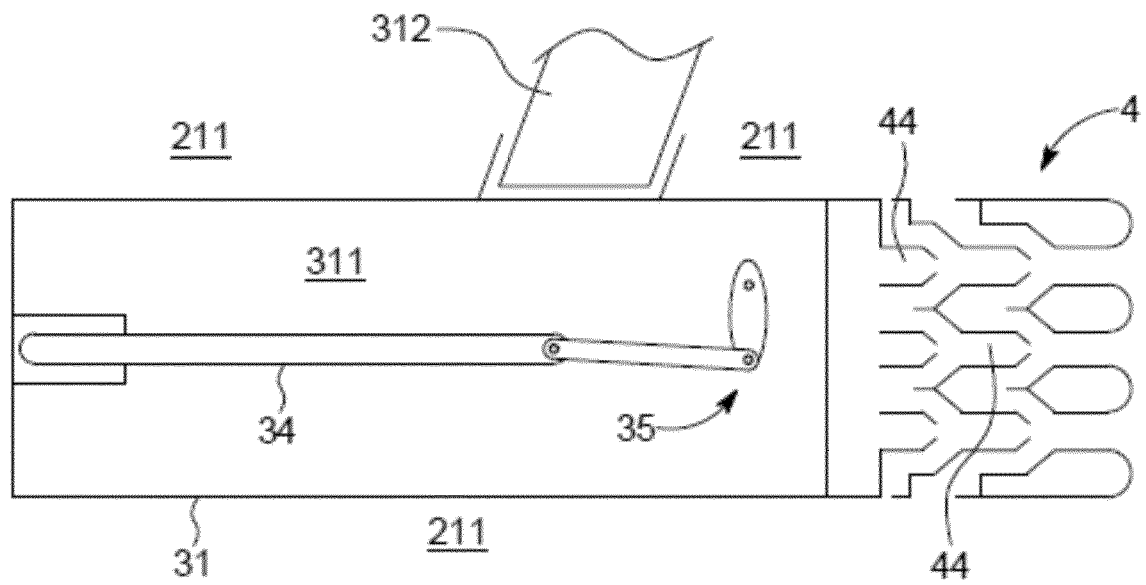


FIG. 5



EUROPEAN SEARCH REPORT

 Application Number
 EP 19 16 9674

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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	WO 2017/162533 A1 (ABB SCHWEIZ AG [CH]) 28 September 2017 (2017-09-28)	1-7,9-15	INV. H01H33/74 H01H33/56
Y	* page 5, line 25 - page 10, line 16 * * page 11, line 34 - page 13, line 4 * * page 13, line 10 - line 14 * * figures 1-5 *	8	
Y	US 4 328 403 A (FRINK RUSSELL E ET AL) 4 May 1982 (1982-05-04) * column 4, line 26 - column 5, line 6 * * figure 1 *	1-3, 8-13,15	
Y	EP 2 120 244 A1 (ABB TECHNOLOGY AG [CH]) 18 November 2009 (2009-11-18) * paragraph [0018] - paragraph [0022] * * figures 1, 2 *	1,3, 8-13,15	
Y	DE 29 47 957 A1 (SPRECHER & SCHUH AG) 4 December 1980 (1980-12-04) * page 7, line 26 - page 9, line 5 * * page 11, line 1 - line 19 * * figure 1 *	1-3, 8-13,15	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 26 September 2019	Examiner Fribert, Jan
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			

EPO FORM 1503 03.82 (P04C01)

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

EP 19 16 9674

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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26-09-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2017162533 A1	28-09-2017	CN 109155217 A	04-01-2019
		EP 3433870 A1	30-01-2019
		US 2019035579 A1	31-01-2019
		WO 2017162533 A1	28-09-2017

US 4328403 A	04-05-1982	NONE	

EP 2120244 A1	18-11-2009	NONE	

DE 2947957 A1	04-12-1980	AT 376837 B	10-01-1985
		CH 645753 A5	15-10-1984
		DE 2947957 A1	04-12-1980
