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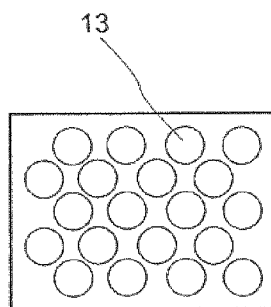


Fig. 2b

(57) Abstract: The electrical switching device (1) comprises an arcing contact arrangement with a first arcing contact (4a) attached to an exhaust tube (6) and a mating second arcing contact (4b). At least a first exhaust volume (7) at least partially surrounding the exhaust tube (6) is further provided. Alternatively or additionally at least a second exhaust volume (8) following the second arcing contact (4b) is provided. The electrical switching device (1) further comprises an exterior volume (9) at least partially surrounding the exhaust tube (6), the first exhaust volume (7) and the second exhaust volume (8). The exhaust tube (6), the first exhaust volume (7), the second exhaust volume (8) and the exterior volume (9) form a travel path for a fluid travelling through them. A plurality of projections (13, 16) extending transversally to the longitudinal axis (z) for cooling down the fluid is provided in the travel path of the fluid.

Electrical switching device

Technical field

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The invention relates to the field of medium and high voltage switching technologies and concerns an electrical switching device according to the independent claim, particularly for a use as an earthing device, a fast-acting earthing device, a circuit breaker, a generator circuit breaker, a switch disconnecter, a combined disconnecter and earthing switch, or a load break switch in power transmission and distribution systems.

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Background

Electrical switching devices are well known in the field of medium and high voltage switching applications. They are e.g. used for interrupting a current when an electrical fault occurs. As an example for an electrical switching device, circuit breakers have the task of opening contacts and keeping them far apart from one another to avoid a current flow, even in case of high electrical potential originating from the electrical fault itself. For the purposes of this disclosure the term medium voltage refers to voltages from 1 kV to 72.5 kV and the term high voltage refers to voltages higher than 72.5 kV. The electrical switching devices, like the circuit breakers, may be required to carry high nominal currents of 4000 A to 6300 A and to switch very high short circuit currents of 40 kA to 80 kA at very high voltages of 110 kV to 1200 kV.

Because of the high nominal current, the electrical switching devices of today require many so-called nominal contact fingers for the nominal current. When disconnecting (opening) a nominal or short circuit

current within the electrical switching devices, the current commutates from nominal contacts of the electrical switching device to its arcing contacts. Analogously, when connecting (closing) the nominal
5 contacts of the electric switching device, the arcing contacts are connected already in advance. They normally comprise as a first arcing contact arcing contact fingers arranged around the longitudinal axis of the electrical switching device in a so-called arcing finger cage and,
10 as a second arcing contact, a rod which is driven into the finger cage.

During the opening process of the electrical switching device an electric arc can form between the first and the second arcing contact, which arc is
15 conductive and still carries electric current even after the mechanical opening of the nominal contacts. In order to interrupt the current, the electrical switching devices contain a dielectrically inert fluid used as an insulating medium and for quenching the electric arc as
20 fast as possible. Quenching the electric arc means extracting as much energy as possible from it. Consequently, a part of the fluid located in the area where the electric arc is generated is considerably heated up (e.g. up to around 20'000-30'000° C) in a very
25 short period of time. Because of the volume expansion of the fluid this part of the fluid builds up a pressure and is ejected from the area where the electric arc burns. In this way the electric arc is blown off about the instant when the current is zero, i.e. during a so-called current
30 zero crossing (CZ). Then the fluid flows into an exhaust tube or volume where it is cooled and redirected by a cooling device. Mixing the cold fluid present in the exhaust tube or volume is only possible to a relatively small extent since the predominant part of the cold gas
35 located inside the exhaust tube or volume is pressed out of the exhaust tube or volume by the hot fluid before any significant mixing is possible. When the hot fluid enters

electric-field-stressed regions, e.g. close to shiel-
dings, unwanted dielectric flashovers may occur, as the
dielectric capabilities, i.e. dielectric insulation
and/or arc extinction capabilities, of the fluid may be
5 lower at higher temperatures. It is therefore necessary
to cool down the fluid as much as possible before it
travels into other regions outside the arcing region of
the switching device.

DE 10 2005 008 098 A1 discloses an SF₆-blast
10 or air-blast gas circuit breaker with improved exhaust
gas cooling in exhaust regions with high electric field
stress. For this purpose, an inner surface of the exhaust
tube is provided with at least 4 rows of circumferential
concave channels. Conventionally, the channels are ground
15 into the exhaust tube in ring shape or spiral shape and
have sharp circumferential channel edges. The channels
are formed into the exhaust tube in ring shape or spiral
shape and have sharp circumferential channel edges. Due
to the concave shape and the sharp edges, the channels
20 provide a gas capturing space for storing or withholding
cold gas. The exhaust gas stream traverses the channels,
is swirled by the sharp channel edges and is thereby
intensively mixed with the cold gas captured inside the
channels and is cooled down. In addition, the inner
25 surface with formed-in channels can be coated with dark
paint to increase radiative heat absorption into the
exhaust tube wall. However, the sharp channel edges must
be shielded from high electric fields to avoid excessive
electric field stress enhancements in high field regions
30 that are in particular present at the end of the exhaust
tube. For this purpose, the exhaust tube is provided with
a channel-free end section of length L. In conclusion,
the sharp-edged circumferential channels are beneficial
for storing cold gas, for creating gas turbulence and for
35 gas mixing, but are detrimental to a smooth electric
field distribution.

Description of the invention

It is an objective of the present invention to improve an electrical switching device with respect to its capabilities of cooling down an arc-extinguishing fluid contained therein. This objective is achieved by the subject-matter of the independent claims. Embodiments are given in the dependent claims and their combinations.

A first aspect of the invention relates to the electrical switching device having a longitudinal axis and including at least a contact arrangement, an arcing zone, an exhaust system and an exterior volume surrounding the exhaust system, wherein at least one travel path for flowing an arc-extinguishing fluid from the arcing zone through the exhaust system to the exterior volume is provided and the travel path comprises a guiding-wall for guiding the fluid, and the guiding-wall comprises in a travel-path section at least one guiding-wall section having a longitudinal extension oriented along a predominant local flow direction in the travel-path section, wherein the at least one guiding-wall section comprises a plurality of projections, that extend transversely to the guiding-wall section, or to a surface of the guiding-wall section, and are for cooling down the fluid, and the projections are arranged repeatedly along a direction orthogonal to the longitudinal extension of the guiding-wall section.

Herein, predominant flow direction is the main flow direction in the region of the travel-path section without considering whirls or vortices occurring in the fluid. Extending transversely shall broadly encompass extensions into the guiding-wall section and/or extensions out of the guiding-wall section. Extending transversely thus means having a directional component orthogonal to the surface or (local) enveloping surface of the guiding-wall section. In particular, the projections extend out of or into an enveloping surface

of the guiding-wall section. Thereby, plural local vortices are generated that positively add-up to increase a heat transfer into walls or elements of the exhaust system.

5 In embodiments:

- the projections are arranged repeatedly along a direction parallel and a direction orthogonal to the longitudinal extension of the guiding-wall section; and/or

10 - the projections are arranged in a two-dimensional arrangement, in particular in a two-dimensional matrix, at the guiding-wall section; and/or

- the projections are arranged in a two-dimensional matrix at the guiding-wall section, and the
15 projections are shaped and dimensioned to produce a two-dimensional matrix of multiple vortices, in particular a two-dimensional arrangement of vortices, along the travel path of the fluid to increase a rate of convective heat transfer from the gas to a surface of the projections;
20 and/or

- the projections are shaped, dimensioned and distanced from one another to produce each exactly one vortex, and the vortices are mutually non-interacting with one another; and/or

25 - at least a part of the projections are arranged in at least two rows extending orthogonal and/or in at least two rows extending parallel and/or in at least two rows extending diagonal to the longitudinal axis z; and/or

30 - at least a part of the projections are arranged in at least two rows and the projections of neighbouring rows are intermeshed, in particular for providing heat transfer over the whole two-dimensional surface of the projection-carrying body; and/or

35 - the projections (13) comprise a shape, in particular two-dimensional shapes selected from the group

consisting of: dimples (13), funnel-like shapes, funnels, cup shapes, and cap shapes; and/or

- the projections are shaped and dimensioned to produce multiple vortices along the travel path of the fluid to increase a rate of convective heat transfer from the gas to a surface of the projections; and/or

- the projections are negative projections extending outwards from the travel path, and/or are positive projections extending inwards into the travel path; and/or

- a number of negative projections in proximity to one another of at most 4 and preferably at most 2 negative projections per cm^2 are provided at the guiding-wall section for providing multiple mutually non-interaction vortices; and/or the negative projections are arranged in a two-dimensional arrangement or two-dimensional matrix at the guiding-wall section, in particular in a two-dimensional arrangement or two-dimensional matrix extending along the longitudinal extension of the guiding-wall section; and/or

- the negative projections are arranged over the whole surface of the guiding-wall section or guiding-wall; and/or

- the projections are arranged repeatedly, in particular periodically, along a direction parallel and/or a direction transversely and/or a direction orthogonal to the longitudinal extension of the guiding-wall section; and/or

- the travel-path section is extending parallel to the longitudinal axis (z), and/or wherein the longitudinal extension of the guiding-wall section is extending parallel to the longitudinal axis z; and/or

- the projections are arranged at guiding-wall sections, preferably at all guiding-wall sections made of metal, along which the fluid flows with high speed, in particular with speeds higher than 0.2 times the speed or local speed of sound; and/or

- the exhaust system comprises at the side of the first arcing contact an exhaust tube and a first exhaust volume at least partially surrounding the exhaust tube, and/or comprises at the side of the second arcing contact at least a second exhaust volume, and

the travel path is formed by the exhaust tube, the first exhaust volume, in particular a first enclosure surrounding the first exhaust volume, and the exterior volume; and/or the travel path is formed by (optionally a second exhaust tube and) the second exhaust volume, in particular a second enclosure surrounding the second exhaust volume, and the exterior volume; in particular wherein the exterior volume is surrounding the exhaust tube, the first exhaust volume, the first enclosure, the second exhaust volume and the second enclosure; and/or

- the contact arrangement is an arcing contact arrangement comprising a first arcing contact and a mating - for example plug-tulip or head-head - second arcing contact, wherein for closing and opening the electric switching device at least one of the arcing contacts is movable and cooperates with the other arcing contact; and/or

- the at least one movable arcing contact is movable parallel to the longitudinal axis z , and/or the first arcing contact is attached to the exhaust tube; and/or

- negative projections are formed by concave structures (i.e. concave as seen by the fluid) in the guiding-wall section for locally swirling the fluid, in particular wherein the negative projections comprise a funnel-like shape or are formed as funnels; and/or

- the guiding-wall is a wall of at least one of: the exhaust tube, the first exhaust volume, a first enclosure, a second enclosure, the exterior volume, and the second exhaust volume.

An embodiment relates to an electrical switching device comprising at least an arcing contact arrangement with a first arcing contact and a mating second arcing contact. For closing and opening the electric switching device at least one of the arcing contacts is movable parallel to a longitudinal axis and cooperates with the other arcing contact. The first arcing contact is attached to an exhaust tube. At least a first exhaust volume at least partially surrounding the exhaust tube is further provided. Additionally or alternatively, a second exhaust volume following the second arcing contact is provided. The electrical switching device further comprises an exterior volume or tank surrounding the exhaust tube, the first exhaust volume and the second exhaust volume. The exhaust tube, the first exhaust volume, the second exhaust volume and the exterior volume form a travel path for a fluid, i.e. arc extinguishing fluid, travelling through them. A plurality of projections extending transversally to the longitudinal axis for cooling down the fluid is provided in the travel path of the fluid.

By providing projections and arranging them in the way in the travel path of the fluid a heat transfer enhancement is achieved. The projections produce extremely stable vortices which increase the rate of convective heat transfer from the gas to the projection surface. This is on the one hand due to the fact that the heat exchange area between the fluid and the ambient is considerably increased by the projection surfaces and on the other hand because the flow pattern and the turbulence of the hot fluid are changed.

Such an improvement of the heat transfer capabilities results in several important benefits for an electrical switching device, e.g. for a high voltage circuit breaker. Consequently it is possible to reduce the size of exhaust volumes and enclosures, to reduce the

risk of dielectric flashovers, and/or to increase a performance rating of the electrical switching device.

In an embodiment at least a part of the projections are arranged in at least two rows, in particular rows extending essentially orthogonal and/or parallel and/or diagonal to the longitudinal axis z; and/or the projections of neighbouring rows are not rotationally invariant under arbitrary rotation angles about the longitudinal axis z. Particularly, projections of neighbouring rows are intermeshed. By arranging at least a part of the projections in intermeshing rows a higher cooling effect is attained because of the "three-dimensional" arrangement of the projections which causes the heat transfer to occur not only perpendicularly with respect to the fluid stream direction but also parallel to the direction.

In one embodiment at least a part of the projections are arranged on at least one guiding-wall section of the exhaust tube and/or the first exhaust volume and/or the second exhaust volume and/or a first enclosure for the first exhaust volume and/or a second enclosure for the second exhaust volume. This arrangement of the projections allows a flexible design of the electrical switching device depending on its geometry and the fluid path. The projections are preferably dimples. By forming at least a part of the projections as dimples the gas cooling is positively influenced because the fluid stream is changed, e.g. with respect to its increased turbulence, along the entire path of the streaming direction.

In one aspect or embodiment of the invention, the electrical switching device comprises at least a tube or a rod arranged in at least one portion of the travel path of the fluid, such that the fluid flows at least partially along an outer surface of the tube or the rod. At least a part of the projections is formed by fluid-deflecting elements arranged on an outer surface, with

respect to the longitudinal axis, of the tube or the rod. Advantageously the provision of such a tube or rod with deflecting elements additionally improves the cooling of the fluid by guiding the portions of it which travel in the middle of the stream towards the walls of the first exhaust tube and/or the first exhaust volume and/or the second exhaust volume. According to this the cooling effect is increased, because the fluid travelling in the middle of the fluid stream is hotter than the boundary portions as this middle portion of the fluid has no contact to any metal wall parts of the electrical switching device, as compared to the boundary portions of the fluid.

In embodiments, the tube or rod with the deflecting elements is advantageously arranged at locations where the fluid travels at least temporarily with supersonic speed, thus increasing the cooling effect by creating "shocks", i.e. discontinuous changes of parameters like pressure.

Preferably, a smallest diameter of the fluid-deflecting elements is equal to a diameter of the tube or the rod, and the diameter of the fluid-deflecting elements increases when moving in a flow direction of the fluid. This increase in diameter of the deflecting elements advantageously allows the generation of multiple of the shocks while keeping the fluid streaming at supersonic speed away from the electric arc area.

In one embodiment at least some of the fluid-deflecting elements are advantageously formed as truncated cone sections, that are arranged on the outer surface of the tube or the rod, and in particular are arranged symmetrically about the tube or the rod.

In another embodiment at least some of the fluid-deflecting elements form frusto-conical surfaces and extend around the tube or the rod, preferably with their symmetry axis being aligned parallel to the longitudinal axis z.

Both shapes of the deflecting elements have proven to optimize the fluid streaming in terms of "shocks" and speed.

Advantageously, a transition from a largest
5 diameter of the fluid-deflecting elements to a diameter of the tube or rod is discontinuous. In one specific embodiment the largest diameter of the fluid-deflecting elements is at least 0.5 times larger than the diameter of the tube or rod. Such "sharp" edges are favourable to
10 a generation of local turbulent fluid sub-streams or vortices in the area of the edges and redirecting at least the middle stream of the fluid towards the stream boundaries.

In embodiments, the tube or rod with the
15 deflecting elements is advantageously arranged at locations where the fluid travels at least temporarily with supersonic speed, thus increasing the cooling effect by creating "shocks", i.e. discontinuous changes of parameters like pressure. The increase in diameter of the
20 deflecting element advantageously allows the generation of multiple shocks while keeping the fluid streaming at supersonic speed away from the electric arc area.

In embodiments at least a part of the projections are arranged on at least one guiding-wall
25 section of an exit channel connecting the exhaust volume to the exterior volume.

In embodiments, the projection(s) or at least one additional projection is formed as inner thread section(s) protruding into an inner wall of the exhaust
30 tube. Preferably, the inner thread sections are interconnected or are extending continuously along a length of the exhaust tube.

In embodiments at least a part of the projections are arranged on at least one guiding-wall
35 section of a heating channel.

In embodiments at least a part of the projections are formed as microscopic projections.

In embodiments at least a part of the projections are non-uniform projections.

In a further aspect, independent of or according to any of the herein disclosed other aspects or
5 embodiments, the invention encompasses an electrical switching device, in particular according to any of the claims or as disclosed herein, having a longitudinal axis and including at least a contact arrangement, an arcing zone, an exhaust system and an exterior volume
10 surrounding the exhaust system, wherein at least one travel path for flowing an arc-extinguishing fluid from the arcing zone through the exhaust system to the exterior volume is provided and the travel path comprises a guiding-wall for guiding the fluid, and the guiding-
15 wall comprises in a travel-path section at least one guiding-wall section having a longitudinal extension oriented along a predominant (i.e. main local) flow direction in the travel-path section, wherein further the at least one guiding-wall section comprises a plurality
20 of negative projections, that extend outwards from the travel path and provide concave volumes in the guiding-wall section for locally swirling the fluid.

A yet further aspect of the invention relates to a method for operating an electrical switching device
25 according to the invention, in particular according to any of the subsequent claims. As mentioned, the electrical switching device has a longitudinal axis and is provided with at least a contact arrangement, an arcing zone, an exhaust system and an exterior volume
30 surrounding the exhaust system. At least one travel path for flowing an arc-extinguishing fluid from the arcing zone through the exhaust system to the exterior volume is provided and the fluid is guided along at least a guiding-wall of the travel path. The guiding-wall is
35 provided in a travel-path section with at least one guiding-wall section having a longitudinal extension oriented along a predominant flow direction in the

travel-path section. A plurality of projections extending transversely to the guiding-wall section is provided for cooling down the fluid along the at least one guiding-wall section.

5

Short description of the drawings

Embodiments, advantages and applications of the invention result from the dependent claims and from
10 the now following description by means of the figures. It is shown in:

Fig. 1 a sectional top view of a basic embodiment of a high voltage circuit breaker;

Fig. 2a a partial sectional view of a wall of
15 an exhaust tube of the circuit breaker of Fig. 1 with a fluid temperature profile;

Fig. 2b a two-dimensional view of a rolled out wall section of the exhaust tube with schematized projections;

20 Fig. 3a to 3e different types of the projections of Fig. 2a and 2b;

Fig. 4 a sectional view of a tube with deflecting elements, arranged inside the exhaust tube of the circuit breaker of Fig. 1;

25 Fig 5a and 5b each a schematic view of an embodiment of the deflecting elements of Fig. 4;

Fig. 6 a partial sectional view of the interior of an exhaust tube with the tube with deflecting elements according to Fig. 4 for the circuit breaker of
30 Fig. 1, with a fluid temperature profile;

Fig. 7 a diagram showing curves of dissipated heat over time for different embodiments of the invention as compared with prior solutions; and

Fig. 8 a sectional view of inner thread
35 elements arranged inside the exhaust tube of the circuit breaker of Fig. 1.

Ways of carrying out the invention

The invention is described for the example of a high voltage circuit breaker with nominal contacts and arcing contacts, but the principles described in the following also apply for the usage of the invention in other switching devices, e.g. of the type mentioned in the introduction.

In the following same reference numerals denote structurally or functionally same or similar elements of the various embodiments of the invention.

Fig. 1 shows a sectional top view of a basic embodiment of a high voltage circuit breaker 1 in an opened configuration. The device is rotationally symmetric about a longitudinal axis z. Only the elements of the circuit breaker 1 which are related to the present invention will be described in the following, other elements present in the figures are not relevant for understanding the invention and are known by the skilled person in high voltage electrical engineering.

A "closed configuration" as used herein means that the nominal contacts and/or the arcing contacts of the circuit breaker are closed. Accordingly, an "opened configuration" as used herein means that the nominal contacts and/or the arcing contacts of the circuit breaker are opened.

The circuit breaker 1 is enclosed by a shell 5 which normally is cylindrical and is arranged around the longitudinal axis z. It comprises a nominal contact arrangement formed by a first nominal contact comprising a plurality of contact fingers 3a, of which only two are shown here for reasons of clarity. The nominal contact fingers 3a are formed as a finger cage around the longitudinal axis z. The nominal contact arrangement further comprises a second mating nominal contact 3b which normally is a metal tube. A shielding 5a is arranged around the first and the second nominal contact

3a, 3b. The circuit breaker 1 furthermore comprises an arcing contact arrangement formed by a first arcing contact 4a and a second arcing contact 4b. Analogously to the first nominal contact 3a also the first arcing contact comprises multiple fingers 4a arranged in a finger cage. The second arcing contact 4b is normally rod-shaped.

The contact fingers 3a, 4a are movable relatively to the contacts 3b, 4b from the closed configuration, in which they are in electrical contact to one another, into the opened configuration shown in Fig. 1, in which they are apart from one another, and vice versa. It is also possible that only one set of the contacts 3a, 4a or 3b, 4b respectively, moves parallel to the longitudinal axis z and the other set of contacts 3b, 4b or 3a, 4a respectively, may be stationary. For the explanatory purposes of the present invention it is assumed that only the second nominal contact 3b and the second arcing contact 4b are movable along the z-axis and the nominal contact finger cage 3a and the first arcing contact 4a are stationary. However, the invention is not limited to this configuration.

As mentioned the circuit breaker 1 is shown during an opening process of the electrical switching device 1 in an instant when the distance between the arcing contacts 4a, 4b is still so small that an electric arc 3 is still present between the arcing contacts 4a, 4b. For the purpose of this disclosure the area around the electric arc 3 is called heating-up area or arcing volume.

The first arcing contact 4a is attached to an exhaust tube 6 and the first nominal contact 3a is attached to a first exhaust volume 7 which at least partially surrounds the exhaust tube 6. A first enclosure 7a is arranged around the first exhaust volume 7. In this embodiment the second arcing contact 4b and the second nominal contact 3b are attached to a second exhaust

volume 8. A second enclosure 8a is arranged around the second exhaust volume 8. The shell 5 defines an exterior volume 9 surrounding the exhaust tube 6, the first exhaust volume 7 and the second exhaust volume 8. The exhaust tube 6, the first exhaust volume 7, the first enclosure 7a, the second exhaust volume 8, the second enclosure 8a and the exterior volume 9 form a travel path 2 for a fluid travelling through them. This travel path is illustrated in Fig. 1 by a plurality of arrows, of which only a few have been denoted by the reference numeral 2. It is noted that the electrical switching device 1 may have less or more exhaust volumes or enclosures, depending on its type. The first exhaust volume 7 and the second exhaust volume 8 comprise first openings 11 in their delimiting walls with the purpose of enabling fluid communication with the exterior volume 9 via the first or the second enclosure 7a, 8a, respectively. The exhaust tube 6 comprises at least a second opening 12 allowing fluid communication between the exhaust tube 6 and the first exhaust volume 7. The heating-up area has fluid connection with both the exhaust tube 6 and the second exhaust volume 8, as shown by the respective arrows 2. This type of circuit breaker is known and will not be described in more detail here. Particularly, it is known how the process of extinguishing the electric arc 3 is carried out by means of a fluid being an extinguishing medium.

Embodiments of an exhaust tube 6 and/or of other elements according to the invention are described in the following and replace the exhaust tube and/or other standard elements shown in Fig. 1.

For the purposes of this disclosure the fluid used for extinguishing the electric arc can be an oil, or SF₆ gas and/or other possible switching gases or any other dielectric insulation medium and arc extinguishing medium, may it be gaseous and/or liquid. Such dielectric insulation medium can for example encompass media com-

prising an organofluorine compound, such organofluorine compound being selected from the group consisting of: a fluoroether, a fluoroamine, a fluoroketone, an oxirane, a hydrofluoroolefin or more generally fluorolefin, and mixtures and/or decomposition products thereof; and preferably being a fluoroketone and/or a fluoroether, more preferably a perfluoroketone and/or a hydrofluoroether. Herein, the terms "fluoroether", "fluoroamine" and "fluoroketone" refer to at least partially fluorinated compounds. In particular, the term "fluoroether" encompasses both hydrofluoroethers and perfluoroethers, the term "fluoroamine" encompasses both hydrofluoroamines and perfluoroamines, and the term "fluoroketone" encompasses both hydrofluoroketones and perfluoroketones, and the term fluoroolefin encompasses both hydrofluoroolefins and perfluoroolefins. It can thereby be preferred that the fluoroether, the fluoroamine, the fluoroketone and the oxirane are fully fluorinated, i.e. perfluorinated.

In embodiments, the dielectric insulation medium is selected from the group consisting of: a (or several) hydrofluoroether(s), a (or several) perfluoroketone(s), a (or several) hydrofluoroolefin(s), and mixtures thereof.

In particular, the term "fluoroketone" as used in the context of the present invention shall be interpreted broadly and shall encompass both fluoromonoketones and fluorodiketones or generally fluoropolyketones. Explicitly, more than a single carbonyl group flanked by carbon atoms may be present in the molecule. The term shall also encompass both saturated compounds and unsaturated compounds including double and/or triple bonds between carbon atoms. The at least partially fluorinated alkyl chain of the fluoroketones can be linear or branched and can optionally form a ring.

In particular, the fluoroketone can be a fluoromonoketone and/or may also comprise heteroatoms,

such as at least one of a nitrogen atom, oxygen atom and sulphur atom, replacing one or more carbon atoms. More preferably, the fluoromonoketone, in particular perfluoroketone, shall have from 3 to 15 or from 4 to 12 carbon atoms and particularly from 5 to 9 carbon atoms. Most preferably, it may comprise exactly 5 carbon atoms and/or exactly 6 carbon atoms and/or exactly 7 carbon atoms and/or exactly 8 carbon atoms.

In embodiments, the dielectric insulation medium comprises at least one compound being a fluoroolefin selected from the group consisting of: hydrofluoroolefins (HFO) comprising at least three carbon atoms, hydrofluoroolefins (HFO) comprising exactly three carbon atoms, trans-1,3,3,3-tetrafluoro-1-propene (HFO-1234ze), 2,3,3,3-tetrafluoro-1-propene (HFO-1234yf), trans-1,2,3,3,3 pentafluoroprop-1-ene (HFO-1225ye (E-isomer)), cis-1,2,3,3,3 pentafluoroprop-1-ene (HFO-1225ye (Z-isomer)), and mixtures thereof.

The dielectric insulation medium can further comprise a background gas or carrier gas different from the organofluorine compound, in particular different from the fluoroether, the fluoroamine, the fluoroketone, the oxirane and the hydrofluoroolefin or generally fluoroolefin, and preferably can be selected from the group consisting of: air, N₂, O₂, CO₂, a noble gas, H₂, NO₂, NO, N₂O, fluorocarbons and in particular perfluorocarbons and preferably CF₄, CF₃I, SF₆; and mixtures thereof.

According to an embodiment, the quenching gas comprises as organofluorine compound a fluoroketone or a mixture of fluoroketones, in particular a fluoromonoketone, and preferably a fluoromonoketone having from 4 to 12 carbon atoms, in particular having exactly 5 or 6 or 7 or 8 carbon atoms.

Fig. 2a shows a partial sectional view of a wall of an exhaust tube 6 for the circuit breaker 1 of Fig. 1 with a fluid temperature profile. In Fig. 2a

"partial section view" means that only a section, particularly a wall profile, of the exhaust tube 6 is shown for reasons of clarity. Furthermore, projections 13 are shown schematically on the wall profile of the exhaust tube 6, which projections 13 in this example are dimples 13. The fluid temperature profile is represented by field lines 14 connecting locations of same temperature. In the area 14a, which is located closest to the heating-up area, the fluid temperature is highest and can amount to about 16'000°C. The farther the fluid travels in a direction opposite to the arrow z the more it is cooled down. The subsequent temperature isolines 14 represent subsequently lower temperatures, when moving in the direction opposite to the arrow z. When the fluid arrives in an area 14b, which corresponds to an area where the fluid escapes into the first exhaust volume 7, thus in the area of the second opening 12, the temperature can already have decreased to about 13'000°C. Please note that such temperature values are purely indicative and are given as exemplary values only.

Fig. 2b shows a two-dimensional rolled out section of the wall of the exhaust tube 6 with projections 13. At least a part of the projections 13 are arranged on at least a wall section of the first exhaust tube 6 and/or of the first exhaust volume 7 and/or of the second exhaust volume 8 and/or of the first enclosure 7a and/or of the second enclosure 8a, and/or of any part of the travel path with hot or hottest exhaust gases being present in the switching device, in particular when moving downstream away from the arcing volume. A plurality of the projections 13 extend transversally to the longitudinal axis z and improve the cooling down of the fluid.

Additionally or alternatively to the above mentioned positions, at least a part of the projections 13 may be arranged on at least one guiding-wall section of an exit channel 20 connecting the exhaust volumes 7

and/or 8 to the exterior volume 9. Said exit channels 20 are shown in Fig. 1. Preferably, the projections 13 are dimples 13.

Additionally or alternatively to the above mentioned positions 13, at least a part of the projections 13 are arranged on at least one guiding-wall section of a heating channel 21. Said heating channel 21 is shown in Fig. 1. Preferably the projections 13 are dimples 13.

10 In Figs. 2a and 2b, the projections 13 are shown as uniform projections 13, thus having a same shape. In other embodiments, at least a part of the projections 13 may be non-uniform projections 13', as schematically shown in Fig. 1. The advantage of this type of non-uniform projections 13' is that the manufacture of
15 the elements having the non-uniform projections 13' is simpler and therefore cheaper.

In one embodiment schematically indicated in Fig. 1, at least a part of the projections 13 may be
20 formed as microscopic projections 13'' (shown as dotted lines). This can be achieved by increasing a surface roughness of the above mentioned guiding-walls having the microscopic projections 13''. In embodiments, a mean roughness (Ra) of a wall section comprising the micro-
25 scopic projections 13'' is larger than a standard surface roughness, e.g. larger than a standard surface roughness of e.g. N9 or N10 and in particular larger than 30 μm . Particularly, the microscopic projections 13'' are characterized by a surface roughness selected in a range
30 of 30 μm to 200 μm , more preferably in a range of 50 μm to 150 μm , and most preferably in a range of 70 μm to 120 μm . This type of microscopic projections 13'' is particularly achieved in connexion with the non-uniform projections 13' in order to drastically simplify their
35 manufacturing process.

However, in generally preferred set-ups applicable to or combinable with all embodiments disclosed

herein (except those with surface-roughness projections 13''), the projections 13 are macroscopic projections 13 (negative or positive) having macroscopic lateral extensions. Such macroscopic projections 13 can be
5 arranged repeatedly along a direction orthogonal to the longitudinal extension of the guiding-wall-section; in particular the macroscopic projections 13 can be arranged in arrays or two-dimensional matrices. In general, the macroscopic projections 13 can be designed such that they
10 can form macroscopic vortices in the exhaust gas stream. In other words, in preferred embodiments, the projections 13 are not microscopic projections 13''.

According to this invention and in complete generality, the cooling effect is strongly enhanced by
15 multiple vortex formation at the plural projections, and by improved multiple-vortex turbulent heat transfer to the body or bodies (in particular body or bodies 6, 7, 8, 7a, 8a) carrying the projections on their surface or surfaces. Best cooling may result, if interactions
20 between vortices is avoided by maintaining sufficient distance between vortices, e.g. at least 1 mm to 2 mm distance.

The projections 13 are provided in the travel path of the fluid and at least a part of them are
25 arranged in rows arranged transversally with respect to the longitudinal axis z. It is noted that the arrangement of projections 13 is not limited to the volumes 6, 7, 8, 7a, 8a mentioned above. In other configurations of the electrical switching device 1 they may be placed wherever
30 the fluid is travelling with high speed in order to ensure an efficient cooling.

Projections of neighbouring rows are advantageously not rotationally invariant with regard to rotations about the longitudinal axis z. In the
35 embodiment according to Fig. 2b projections 13 of neighbouring rows are intermeshed, as can be seen in the figure.

The term "intermeshed" in the context of this disclosure means staggered. For example, intermeshed can mean that at least one imaginary straight line can be laid (i) in a surface area comprising at least partly two
5 neighbouring rows, and (ii) can intersect projections 13 of at least two, preferably exactly two, neighbouring rows. "Straight line" here means that the line is not curved when the surface were unrolled in a plane, but does not exclude that the surface itself is bent, e.g.
10 bent about the longitudinal axis z to form a cylindrical projection-carrying body and correspondingly a cylindrical projection-carrying surface.

In embodiments, upon rotations about the longitudinal axis z, there are rotation angles possible
15 under which a first row will at least partially coincide with or cover a second (imaginarily un-rotated) row, typically the next neighbouring row. Such an intermeshed arrangement of projections allows optimal heat transfer over the whole two-dimensional surface of the projection-carrying body .
20

This advantageously further improves the heat transfer between the fluid and the exhaust tube 6 in a transversal direction and also in a direction parallel to the fluid stream. This results from the three-dimensional
25 structure of the dimples, which creates vortices that affect the local heat transfer also in directions parallel to the fluid stream. The dimpled surface projection means that there are concave structures (concave as seen by the fluid) present on the surface of
30 the heat transfer body. The fluid vortices form in or originate from the inside of these concave structures which enhances the heat transfer from gas to the metal surface of the heat transfer body. In other words, the advantageously improved heat transfer effect of the
35 projections 13 originates from the formation of very stable fluid vortices inside and above each projection 13, which vortices intensify a rate of convective heat

transfer from the fluid to the surface having the projections 13. By this, the heat transfer coefficient may be increased at least by about 25% - 40%. At the same time, no significant increase in the pressure drop as compared to surfaces without projections is observed. Furthermore, a better heat transfer is also reached because of an increase of the metal surface of the exhaust tube wall by the presence of the projections, which surface increase accounts for about 4% of the percentage increase of the heat transfer coefficient of 25% - 40% mentioned above.

The projections 13 can be used in areas where the fluid travels either with subsonic or with supersonic speed and they are oriented towards the exterior of the exhaust tube 6 and/or of the first exhaust volume 7 and/or of the second exhaust volume 8. The orientation towards the exterior of the corresponding wall is advantageous for a better heat transfer. However they may also be oriented towards the interior of the tube or volumes.

Furthermore, also the first and/or the second enclosure 7a, 8a may comprise projections in sections of their walls, particularly in sections of the walls where the fluid travels with high speed. In the present context high speed means speeds which are in the range of more than 0.2 times the speed of sound.

In embodiments, a Reynolds number based on a hydraulic diameter of the exhaust tube, and/or the first exhaust volume and/or the second exhaust volume can range between 10000 and 40000.

In embodiments, a ratio between a projection depth and a projection footprint-diameter can range between 0.2 and 0.4; and/or a ratio between a height of the projection and the projection footprint-diameter or side length ranges between 0.1 and 1.0, preferably between 0.4 and 0.6, and most preferred is 0.5.

In embodiments, a ratio between a projection height and the projection footprint diameter can be in a range between 0.4 and 0.6, and in particular is 0.5. The projection height refers to the maximum height of a projection.

Fig. 3a to 3e show examples of different types of the projections 13 of Fig. 2a and 2b. At least a part of the projections 13 can be shaped as an ellipsoid cup (or ellipsoid cap) and/or as a spherical cup (or spherical cap) and/or as a cube (concave or convex) and/or as a rectangular cuboid (concave or convex) and/or as a triangular cuboid (concave or convex). In Fig. 3a the projections are shaped as an ellipsoid cup with a height d , a maximum radius a and a minimum radius b . Fig. 3b shows a projection with a shape of a spherical cup with a height d and a radius r_1 . The ratio between the height d and the radius r_1 can be chosen between 0.1 and 0.5. Fig. 3c shows a projection in the shape of a cuboid with a height d and side lengths a . The ratio between the height d and the side length a ranges between 0.1 and 1.0. Fig. 3d shows a projection as a rectangular cuboid with a height d , a large side length f and a short side length g . Fig. 3e shows a projection as a triangular cuboid with a height d and sides or side lengths i . The ratio between the height d and a side length i can range between 0.1 and 1.0. It is understood that other shapes may readily be used.

In Fig. 2a, 2b; 3a, 3b, 3c, 3d and 3e the projections 13 can be negative projections 13 extending outwards from the travel path, and/or can be positive projections 13 extending inwards into the travel path. Preferably, the projections 13 are negative projections 13 formed by concave structures in the guiding-wall section for locally swirling the fluid. They may comprise a funnel-like shape or be formed as a whole as funnels. Herein, cup-shaped means negative projection or concave projection (concave as seen by the fluid); as well cap-

shaped means positive projection or convex projection (convex as seen by the fluid) and is possible in addition to or as alternative to cup-like shapes (as shown in the context of the figures), but is less preferred.

5 Fig. 4 shows a sectional view of a rod 15 with deflecting elements 16 arranged inside the exhaust tube 6. The tube 15 is arranged in at least one portion of the travel path of the fluid such that the fluid flows at least partially along an outer surface of the tube or
10 the rod 15, particularly in a portion thereof the fluid travelling at least temporarily with supersonic speed. Advantageously, the tube 15 is attached to the exhaust tube 6 and/or is arranged concentrically inside the exhaust tube 6 (as shown in Fig. 4). The projections,
15 which are formed as the fluid-deflecting elements 16 in this embodiment, are arranged on an outer surface of the tube 15 and are oriented such that their symmetry axes are aligned parallel to the longitudinal axis z . The tube 15 is dimensioned such that a ratio of its radius r to
20 its distance R from its axis to an inner wall surface of the exhaust tube 6 can range between 0.1 and 0.5. The fluid-deflecting elements 16 are dimensioned in such a way that a ratio between their maximum radius h and their elongation s in the longitudinal direction z ranges
25 between 0.1 and 1.0 and a ratio between a distance L between two next-neighbouring fluid-deflecting elements 16 and the maximum radius h ranges between 2 and 10.

As can be seen in Fig. 4, a transition from a largest diameter $2 \cdot h$ of the fluid-deflecting elements 16
30 to a diameter $2 \cdot r$ of the tube 15 is discontinuous. Advantageously, the largest diameter $2 \cdot h$ of the fluid-deflecting elements 16 is at least 0.5 times larger than the diameter $2 \cdot r$ of the tube 15. By choosing the dimensions it is made sure that the fluid stream is
35 optimally deflected from the interior of the stream towards the walls of the exhaust tube 6. It is noted that these dimensions may deviate from the ranges disclosed

herein, particularly in case the tube 15 with the deflection elements 16 is used at another location in the fluid travel path.

As mentioned, the element 15 is a tube 15; however it may also be a rod 15. A tube 15 which is open at both extremities (not shown), is preferred, because it allows a portion of the fluid to also travel through its interior, thus increasing the cross section of the travel path of the fluid, such that the fluid may escape faster from the heating-up area or arcing volume.

Fig. 5a and 5b each shows a detailed schematic view of an embodiment of the deflecting elements of Fig. 4. Preferably, the fluid-deflecting elements 16 comprises steel or are made of steel.

In the embodiment according to Fig. 5a the fluid-deflecting elements 16 form frustoconical surfaces and extend around the tube 15, in particular with their symmetry axis being aligned parallel to the longitudinal axis z . A smallest diameter of the fluid-deflecting elements 16, denoted by the reference 17a, can be made equal to the diameter $2 \cdot r$ of the tube 15. The diameter of the fluid-deflecting elements 16 increases in the flow direction of the fluid (opposite to the arrow z) up to the maximum diameter denoted by 17b (which equals $2 \cdot h$ in Fig 4).

In the embodiment according to Fig. 5b the fluid-deflecting elements 16 are formed as truncated cone sections 16a, 16b arranged on the outer surface of the tube 15), and in particular are arranged symmetrically about the tube 15 or the rod 15. As mentioned in the context of the projections 13 arranged on the wall of the exhaust tube 6, also the truncated cone sections 16a, 16b can be arranged in rows around the tube 15 and can be intermeshed, as can be seen in Fig. 5b. In Fig. 5b only a single cone section 16b of a second row of fluid-deflecting elements 16 is shown because of clarity reasons.

The usage of the tube 15 with the fluid-deflecting elements 16; 16a, 16b is particularly effective in areas where the fluid travels with supersonic speed and helps to create the "shocks" or "shock waves" mentioned at the beginning. It is advantageous to form the fluid-deflecting elements 16; 16a, 16b in the way described above in order to keep up the supersonic speed of the fluid also after it has passed the first fluid-deflecting element 16; 16a, 16b. For example, if the fluid-deflecting elements would not have the cone shape, but would be vertical on the side exposed to the fluid stream, a shock would only be generated at the first fluid-deflecting element and after that the fluid speed would be subsonic. This is not desirable, because on the one hand its speed away from the heating-up area would obviously be lower and on the other hand because the deflecting effect of the fluid-deflecting elements would decrease substantially. By using the shapes further shocks are generated at the location of fluid-deflecting elements arranged downstream from the first fluid-deflecting element. These shocks reach the wall of the exhaust tube 6 and increase the heat transfer into the wall, in particular by a local increase of the shear stress in the wall.

Therefore, the projections or specifically fluid-deflecting elements 16; 16a, 16b shall be shaped such that they offer to the fluid flow (i) a smooth or continuous increase of their cross-section at their upstream-side end region and (ii) an abruptly changing or discontinuous decrease of their cross-section at their downstream-side end region. This allows to generate shock waves with increased heat transfer onto neighbouring shock-wave receiving surface areas along the fluid flow path and still to maintain an overall supersonic flow speed downstream of such projections 16 or fluid-deflecting elements 16; 16a, 16b.

By using the tube 15 with the fluid-deflecting elements 16; 16a, 16b the heat transfer coefficient may be increased by about 27%. Besides, a better heat transfer is also reached because of an increase of the metal surface, which accounts for around 14% of the percentage mentioned above.

Fig. 6 shows a partial sectional view of the interior of an exhaust tube 6 with a rod 15 with deflecting elements 16 according to Fig. 4 or 5a or 5b for the circuit breaker of Fig. 1, with a fluid temperature profile. In Fig. 6 "partial section view" means that only a section of rod 15 is shown for reasons of clarity. Like in the case of Fig. 2 field lines are denoted by the reference numeral 14. As can be seen, the fluid travelling in the opposite direction of arrow z is deflected by the fluid-deflecting elements 16 towards the wall of the exhaust tube 6. Again, like in Fig. 2, on the right side of Fig. 6 the fluid is hottest, because it is closest to the heating-up area. The more it travels towards the second opening 12 the more it is cooled down. One can also see that the shock magnitude decreases after each fluid-deflecting element 16 (indicated by the decreasing size of "white" areas between two consecutive deflecting elements). The most pronounced deflections take place in an area where the fluid is hottest and fastest, thus yielding the best heat transfer capability in this area. Consequently, a faster cooling is reached.

The tube 15 with the fluid-deflecting elements 16 can either be used in conjunction with an exhaust tube 6 with the projections 13 mentioned above or in regular electrical switching devices 1 having exhaust tubes with smooth walls. Particularly, the tube 15 can be used for retrofit to improve cooling of exhaust gases in existing electrical switching devices by simply mounting the tube 15 with the fluid-deflecting elements 16 inside the exhaust area of the switching devices, particularly in circuit breakers in their exhaust volumes, as the case may be.

As compared to known electrical switching devices the cooling effect is particularly distinctly improved in those regions where the fluid has already passed a longer path. In known electrical switching
5 devices the longer the fluid travels the more its boundary portions are cooled by the metal walls while keeping the middle or internal portion still relatively hot. As in such devices there are no obstacles in the fluid stream the stream remains substantially laminar,
10 such that a considerably weaker mixture of the fluid's boundary portions and middle or internal portions is achieved as compared with the turbulent stream induced by using the tube 15 with the deflecting elements 16 and/or deflecting element sections 16a, 16b.

15 This concept of a rod 15 with deflecting elements 16 arranged inside the exhaust tube 6, as disclosed in connection with the Figs. 4, 5a, 5b, and 6, can be implemented independently of the other projections 13, 13', 13'', 22 disclosed herein.

20 Fig. 7 shows a diagram with curves of dissipated heat over time for different embodiments of the invention, as compared to a prior art solution. The dashed curve 17 represents the heat dissipation for the embodiment of a circuit breaker with the tube 15 and
25 fluid-deflecting elements 16 according to Fig. 4. The dashed-dotted curve 18 shows the heat dissipation for the embodiment of a circuit breaker with the projections 13 on the wall of the exhaust tube 6 according to Fig. 2a, and the solid curve 19 shows the heat dissipation for an
30 embodiment of a circuit breaker according to the prior art without such heat transfer enhancement means. The axis of abscissas represents the time around the instant when the current crosses the value zero in milliseconds, and the axis of ordinates represents the energy absorbed
35 by the exhaust tube 6 in megajoule. As can be seen, the three solutions have similar values in the left part of the diagram (up to about 10 ms before the current

approaches current zero). This is due to the fact that the fluid has not yet been heated up to such an extent that it streams very fast through the exhaust tube. The more the fluid is heated by the electric arc the more its temperature and volume rises and a fast stream through the exhaust tube is created (see arrows 2 in Fig. 1). In this period until the electric arc is blown off, the heat transfer capabilities of the embodiments according to the present invention are clearly higher than in the case of the prior-art electric switching device. The heat transfer capabilities are even higher if both solutions according to the invention are used jointly, which is not explicitly shown in the diagram.

Fig. 8 shows a sectional view of at least one inner thread section 13, 22 arranged inside the exhaust tube 6. The inner thread elements 22 are preferably negative projections 13, 22 formed as cavities in the inner wall 23 of the exhaust tube 6. Fig. 8 shows the exhaust tube 6 in a partial "transparent" way to better illustrate the inner thread or swirl 22. At least a part of the inner thread sections 22 may be connected to one another and may thus form one or more channels 22 in the wall of the exhaust tube 6. This concept of exhaust tube 6 with inner thread section projections 22 or continuous inner thread projections 22 can be implemented independently of the other projections disclosed herein.

By arranging projections in the path of the fluid of an electrical switching device it is possible to increase the heat dissipation capabilities of such an electric switching device. Thereby, projections are arranged in the path of the fluid stream. It is possible to use either projections arranged on the wall of the exhaust tube and/or the exhaust volumes of the electric switching device or a rod or tube with fluid-deflecting elements located outside the rod or tube and at the same time inside the exhaust tube or inside the exhaust volumes or inside a combination thereof, depending on the

requirements of the respective electrical switching device. By an improved cooling of the hot fluid less volume is necessary and the overall size of the electrical switching device can be reduced and it can be made more compact, or the electrical rating of the switching device can be up-graded. Particularly, the fluid cooling according to the invention is also advantageous in non-SF₆ circuit breakers. By the measures described above it is possible to improve the dielectric behaviour of such circuit breakers for example to an extent such that they achieve ratings comparable to SF₆-circuit breakers.

With regard to non-SF₆ circuit breakers, the measures 13, 13', 13'', 16, 22, described above are particularly advantageous when using said fluoroketones as alternative environmentally friendly gas instead of SF₆-circuit breakers, because the projections 13, 13', 13'', 16, 22 may be designed for limiting the gas temperatures, at least temporarily and/or in certain regions of the exhaust system 6, 7, 8, to values that do not exceed a dissociation temperature of the fluoroketones. Consequently, the use of projections 13, 13', 13'', 16, 22 on guide-walls in the path of the insulating gas does not only help to prolong the lifetime of the electrical switching device 1, but they also contribute to design more environmentally friendly high-voltage or medium-voltage electrical switching devices 1 and in particular to improve the usage of fluoroketones as dielectric insulation and arc extinction medium.

In any embodiments, the exterior volume 9 (or its shell 5) can be at least partially surrounding the exhaust system 6, 7, 8 or can be completely surrounding the exhaust system 6, 7, 8. In other words, the exterior volume 9 or the shell 5 delimiting the exterior volume 9 surrounds at least exhaust outlets for receiving exhaust gas coming from the arcing zone; the exterior volume 9 or the shell 5 delimiting the exterior volume 9 can be, but

need not be, a closed volume or a closed shell 5,
respectively.

While there are shown and described presently
preferred embodiments of the invention, it is to be
5 distinctly understood that the invention is not limited
thereto but may otherwise variously be embodied and
practised within the scope of the following claims.
Therefore, terms like "preferred" or "in particular" or
"particularly" or "advantageously", etc. signify optional
10 and exemplary embodiments only.

List of reference numerals

15	1	= basic circuit breaker
	2	= fluid path
	3	= electric arc
	3a	= contact finger of first nominal contact
	3b	= second nominal contact
20	4a	= first arcing contact
	4b	= second arcing contact
	5	= shell
	5a	= shielding
	6	= exhaust tube
25	7	= first exhaust volume
	7a	= first enclosure
	8	= second exhaust volume
	8a	= second enclosure
	9	= exterior volume
30	11	= first openings in exhaust volumes
	12	= second opening in exhaust tube
	13	= projection, macroscopic projection, negative projection, dimple, positive projection, uniform projection, non-uniform projection
35	13'	= non-uniform projection, macroscopic projection
	13''	= microscopic projection, surface roughness projection
	14	= field line

- 14a = hottest zone in exhaust tube
14b = coolest zone in exhaust tube
15 = tube or rod carrying deflecting elements
16 = projection as deflecting element
5 16a = cone section of first row
16b = cone section of second row
17 = heat dissipation curve of embodiment with tube 15
17a = diameter of tube or rod 15
17b = maximum diameter of deflecting element
10 18 = heat dissipation curve of embodiment with dimples
19 = heat dissipation curve of prior art
20 = exit channel from exhaust volume to exterior volume
21 = heating channel
22 = inner thread section
15 23 = exhaust tube wall
24 = interior of exhaust tube
- a = maximum radius of ellipsoid
b = minimum radius of ellipsoid
20 d = height
e = side of cuboid
f = large side of rectangular cuboid
g = short side of rectangular cuboid
h = maximum radius of deflecting element
25 i = side of triangular cuboid
r = radius of tube 15
r1 = radius of sphere
s = elongation of deflecting element
L = distance between two consecutive deflecting elements
30 R = distance from tube 15 to inner wall surface of
exhaust tube
z = longitudinal axis.

Claims

1. Electrical switching device (1) having a longitudinal axis (z) and including at least a contact arrangement (4a, 4b), an arcing zone, an exhaust system (6, 7, 8) and an exterior volume (9) surrounding the exhaust system (6, 7, 8),

wherein at least one travel path for flowing an arc-extinguishing fluid from the arcing zone through the exhaust system (6, 7, 8) to the exterior volume (9) is provided and the travel path comprises a guiding-wall for guiding the fluid, and the guiding-wall comprises in a travel-path section at least one guiding-wall section having a longitudinal extension oriented along a predominant flow direction in the travel-path section,

wherein further the at least one guiding-wall section comprises a plurality of projections (13, 16), that extend transversely to the guiding-wall section and are for cooling down the fluid, wherein

the projections (13, 16) are arranged repeatedly along a direction orthogonal to the longitudinal extension of the guiding-wall section.

2. Electrical switching device (1) according to claim 1, wherein the projections (13, 16) are arranged repeatedly along a direction parallel and a direction orthogonal to the longitudinal extension of the guiding-wall section.

3. Electrical switching device (1) according to any one of the preceding claims, wherein the projections (13, 16) are arranged in a two-dimensional arrangement, in particular in a two-dimensional matrix, at the guiding-wall section.

4. Electrical switching device (1) according to any one of the preceding claims, wherein the

projections (13, 16) are shaped and dimensioned to produce multiple vortices, in particular a two-dimensional arrangement of vortices, along the travel path of the fluid to increase a rate of convective heat transfer from the gas to a surface of the projections (13, 16).

5. Electrical switching device (1) according to any one of the preceding claims, wherein the projections (13, 16) are arranged in a two-dimensional matrix at the guiding-wall section, and the projections (13, 16) are shaped and dimensioned to produce a two-dimensional matrix of multiple vortices along the travel path of the fluid to increase a rate of convective heat transfer from the gas to a surface of the projections (13, 16).

6. Electrical switching device (1) according to any one of the preceding claims, wherein the projections (13, 16) are shaped, dimensioned and distanced from one another to produce each exactly one vortex, and the vortices are mutually non-interacting with one another.

7. Electrical switching device (1) according to any one of the preceding claims, wherein at least a part of the projections (13, 16) are arranged in at least two rows extending orthogonal and/or in at least two rows extending parallel and/or in at least two rows extending diagonal to the longitudinal axis (z).

30

8. Electrical switching device (1) according to any one of the preceding claims, wherein at least a part of the projections (13, 16) are arranged in at least two rows and the projections (13, 16) of neighbouring rows are intermeshed, in particular for providing heat transfer over the whole two-dimensional surface of the projection-carrying body (6, 7, 8, 7a, 8a).

9. Electrical switching device (1) according to any one of the preceding claims, wherein the projections are negative projections (13) extending outwards from the travel path, and/or are positive
5 projections (13, 16) extending inwards into the travel path.

10. Electrical switching device (1) according to any one of the preceding claims, wherein the
10 projections (13) comprise a shape, in particular two-dimensional shape selected from the group consisting of: dimples (13), funnel-like shapes, funnels, cup shapes, cap shapes, and combinations thereof.

15 11. Electrical switching device (1) according to any one of the preceding claims, wherein a number of negative projections (13), in proximity to one another, of at most 4, in particular at most 2, projections per cm^2 are provided at the guiding-wall section for
20 providing multiple mutually non-interacting vortices.

12. Electrical switching device (1) according to any one of the preceding claims, wherein the negative
projections (13) are arranged in a two-dimensional
25 arrangement or two-dimensional matrix at the guiding-wall section, in particular in a two-dimensional arrangement or two-dimensional matrix extending along the longitudinal extension of the guiding-wall section; and/or wherein the negative projections (13) are arranged over the whole
30 surface of the guiding-wall section or guiding-wall.

13. Electrical switching device (1) according to any one of the preceding claims, wherein the
projections (13, 16) are arranged periodically along a
35 direction parallel and a direction orthogonal to the longitudinal extension of the guiding-wall section.

14. Electrical switching device (1) according to any one of the preceding claims, wherein the travel-path section is extending parallel to the longitudinal axis (z), and/or wherein the longitudinal extension of the guiding-wall section is extending parallel to the longitudinal axis (z).

15. Electrical switching device (1) according to any one of the preceding claims, wherein the projections (13, 16) are arranged at guiding-wall sections, preferably at all guiding-wall sections made of metal, along which the fluid flows with high speed, in particular with speeds higher than 0.2 times the speed of sound.

16. Electrical switching device (1) according to any of the preceding claims, wherein the exhaust system (6, 7, 8) comprises at the side of the first arcing contact (4a) an exhaust tube (6) and a first exhaust volume (7) at least partially surrounding the exhaust tube (6) and/or comprises at the side of the second arcing contact (4b) at least a second exhaust volume (8), and

the travel path is formed by the exhaust tube (6), the first exhaust volume (7), in particular a first enclosure (7a) surrounding, in particular partly surrounding or completely surrounding, the first exhaust volume (7), and the exterior volume (9); and/or the travel path is formed by the second exhaust volume (8), in particular a second enclosure (8a) surrounding the second exhaust volume (8), and the exterior volume (9); in particular wherein the exterior volume (9) is surrounding the exhaust tube (6), the first exhaust volume (7), the first enclosure (7a), the second exhaust volume (8) and the second enclosure (8a).

17. Electrical switching device (1) according to any of the preceding claims, the contact arrangement (4a, 4b) is an arcing contact arrangement comprising a first arcing contact (4a) and a mating second arcing contact (4b), wherein for closing and opening the electric switching device (1) at least one of the arcing contacts (4a, 4b) is movable and cooperates with the other arcing contact (4b, 4a).

18. Electrical switching device (1) according to claim 17, wherein the at least one movable arcing contact is movable parallel to the longitudinal axis (z), and/or the first arcing contact (4a) is attached to the exhaust tube (6).

19. Electrical switching device (1) according to any of the preceding claims, wherein at least a part of the projections (13) are arranged on at least one guiding-wall section of the exhaust tube (6) and/or the first exhaust volume (7) and/or the second exhaust volume (8) and/or a first enclosure (7a) for the first exhaust volume (7) and/or a second enclosure (8a) for the second exhaust volume (8), particularly wherein the projections (13) are dimples (13).

20. Electrical switching device (1) according to any one of the preceding claims, in particular according to claim 16, wherein at least a part of the projections (13) are arranged on at least one guiding-wall section of an exit channel (20) connecting the exhaust volume (7, 8) to the exterior volume (9), particularly wherein the projections are dimples (13).

21. Electrical switching device (1) according to any one of the preceding claims, wherein at least a part of the projections (13) are arranged on at least one guiding-wall section of a heating channel (21) of the electrical switching device (1), particularly wherein the projections are dimples (13).

22. Electrical switching device (1) according to any one of the preceding claims, wherein at least a part of the projections (13) are uniform projections (13); and/or wherein at least a part of the projections
5 (13) are non-uniform projections (13'); and/or wherein at least a part of the projections (13) are macroscopic projections (13, 13', 16).

23. Electrical switching device (1) according
10 to any one of the preceding claims, wherein at least a part of the projections are formed as microscopic projections (13''), particularly wherein a mean roughness (Ra) of a wall section comprising the microscopic projection (13'') is selected in a range of 30 μm to 200 μm and
15 more preferably in a range of 50 μm to 150 μm and most preferably in a range of 70 μm to 120 μm ; or wherein none of the projections (13) are formed as microscopic projections (13'') but instead are macroscopic projections (13, 13').

20

24. Electrical switching device (1) according to any one of the preceding claims, wherein at least one additional projection (22) is formed as inner thread section(s) (22) protruding into an inner wall (23) of the
25 exhaust tube (6), particularly wherein the inner thread sections (22) are interconnected or at least one inner thread section (22) is extending continuously along a length of the exhaust tube (6).

30 25. Electrical switching device (1) according to any one of the preceding claims, wherein at least a part of the projections (13, 16) are arranged in at least two rows; and/or the projections (13, 16) of neighbouring rows are not rotationally invariant under arbitrary
35 rotation angles about the longitudinal axis (z).

26. Electrical switching device (1) according to any one of the preceding claims, wherein negative projections (13) are formed by concave structures in the guiding-wall section for locally swirling the fluid, in particular wherein the negative projections (13) comprise a funnel-like shape or are formed as funnels.

27. Electrical switching device (1) according to any of the preceding claims, wherein at least a part of the projections (13) are negative projections (13) shaped as an ellipsoid cup and/or as a spherical cup and/or as a concave cube and/or as a concave rectangular cuboid, and/or as a concave triangular cuboid.

28. Electrical switching device (1) according to any of the preceding claims, wherein at least a part of the projections (13) are positive projections (13) shaped as an ellipsoid cap, and/or as a spherical cap, and/or as a convex cube, and/or as a convex rectangular cuboid, and/or as a convex triangular cuboid.

29. Electrical switching device (1) according to any of the preceding claims, wherein a ratio between a depth of the projection (13) and a footprint diameter of the projection (13) ranges between 0.2 and 0.4; and/or wherein a ratio between a height of the projection (13) and the footprint-diameter or side length ranges of the projection (13) between 0.1 and 1.0, preferably between 0.4 and 0.6, and most preferred is 0.5.

30

30. Electrical switching device (1), in particular according to any of the preceding claims, having a longitudinal axis (z) and including at least a contact arrangement (4a, 4b), an arcing zone, an exhaust system (6, 7, 8) and an exterior volume (9) surrounding, in particular at least partially surrounding or completely surrounding, the exhaust system (6, 7, 8),

wherein at least one travel path for flowing an arc-extinguishing fluid from the arcing zone through the exhaust system (6, 7, 8) to the exterior volume (9) is provided and the travel path comprises a guiding-wall for guiding the fluid, and the guiding-wall comprises in a travel-path section at least one guiding-wall section having a longitudinal extension oriented along a predominant flow direction in the travel-path section,

wherein further the at least one guiding-wall section comprises a plurality of projections (13, 16), that extend transversely to the guiding-wall section and are for cooling down the fluid,

the electrical switching device (1) further comprising at least a tube (15) or a rod (15), particularly a tube (15) which is opened at its both extremities, arranged in at least one portion of the travel path of the fluid, such that the fluid flows at least partially along an outer surface of the tube (15) or the rod (15), particularly in a portion thereof the fluid traveling at least temporarily with supersonic speed, wherein at least a part of the projections (16) is formed by fluid-deflecting elements (16) arranged on the outer surface of the tube (15) or the rod (15).

31. Electrical switching device (1) according to claim 30, wherein the fluid-deflecting elements (16) are for generating shock waves with increased heat transfer onto neighbouring shock-wave receiving surface areas along the fluid flow path while still maintaining an overall supersonic flow speed down-stream of such fluid-deflecting elements (16; 16a, 16b), in particular wherein the shock waves reach a wall of the exhaust system (6, 7, 8) or of the exhaust tube (6) and increase a heat transfer into the wall.

32. Electrical switching device (1) according to any one of the claims 30 to 31,

wherein a smallest diameter of the fluid-deflecting elements (16) is equal to a diameter of the tube (15) or the rod (15) and the diameter of the fluid-deflecting elements (16) increases when moving in a flow direction of the fluid; and/or

wherein at least some of the fluid-deflecting elements (16) are formed as truncated cone sections (16a, 16b), that are arranged on the outer surface of the tube (15) or the rod (15), and in particular are arranged symmetrically about the tube (15) or the rod (15).

33. Electrical switching device (1) according to any one of the claims 30 to 32, wherein at least some of the fluid-deflecting elements (16) form frusto-conical surfaces and extend around the tube (15) or the rod (15), preferably with their symmetry axis being aligned parallel to the longitudinal axis (z).

20

34. Electrical switching device (1) according to any one of the claims 30 to 33, wherein a transition from a largest diameter (h) of the fluid-deflecting elements (16) to a diameter (r) of the tube (15) or the rod (15) is discontinuous, particularly wherein the largest diameter (h) of the fluid-deflecting elements (16) is at least 0.5 times larger than the diameter (r) of the tube (15) or the rod (15).

35. Electrical switching device (1) according to any of the claims 30 to 34, wherein the tube (15) is dimensioned such that a ratio between its radius (r) and its distance (R) from its axis to an inner wall surface of the exhaust tube (6) ranges between 0.1 and 0.5.

35

36. Electrical switching device (1) according to any one of the claims 30 to 35, wherein the fluid-

deflecting elements (16) are dimensioned in such a way that a ratio between their maximum radius (h) and their elongation (s) in the longitudinal direction (z) ranges between 0.1 and 1.0, and/or a ratio between a distance
5 (L) between two next-neighbouring fluid-deflecting elements (16) and a maximum radius (h) of the deflecting elements (16) ranges between 2 and 10.

37. Electrical switching device (1) according
10 to any one of the claims 30 to 36, wherein the rod (15) or the tube (15) is attached to the exhaust tube (6) and/or is arranged concentrically inside the exhaust tube (6).

15 38. Electrical switching device (1) according to any one of the preceding claims, wherein the fluid is an oil, or is SF₆ gas and/or a dielectric insulation and arc extinguishing medium or gas comprising an organofluorine compound, in particular the organofluorine
20 compound being selected from the group consisting of: a fluoroether, a fluoroamine, a fluoroketone, an oxirane, a fluoroolefin, and mixtures and/or decomposition products thereof, in particular in a mixture with a background gas.

25 39. Electrical switching device (1) according to any one of the preceding claims, it being an earthing switch, a fast-acting earthing switch, a circuit breaker, a generator circuit breaker, a switch disconnecter, a
30 combined disconnecter and earthing switch, or a load break switch.

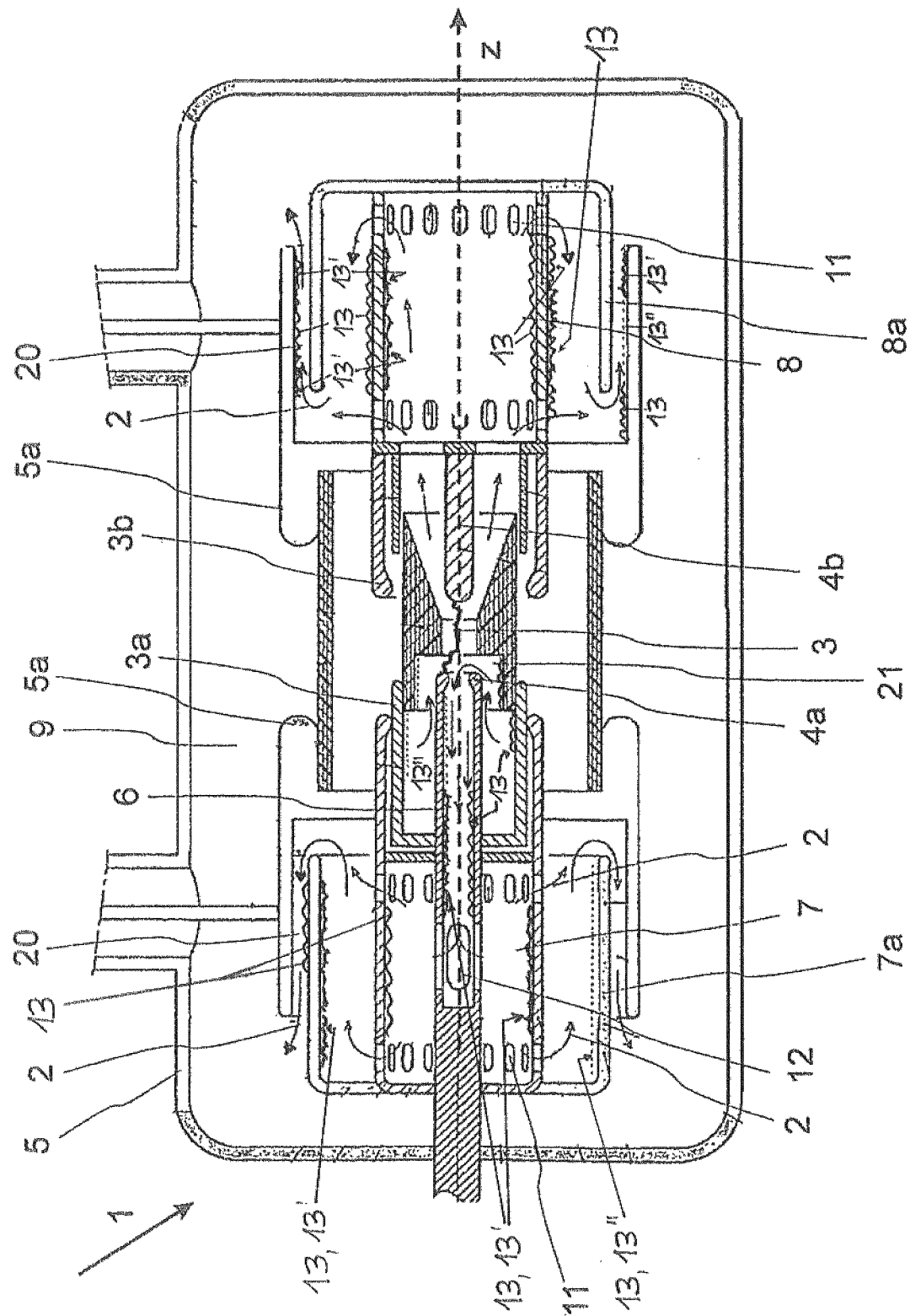
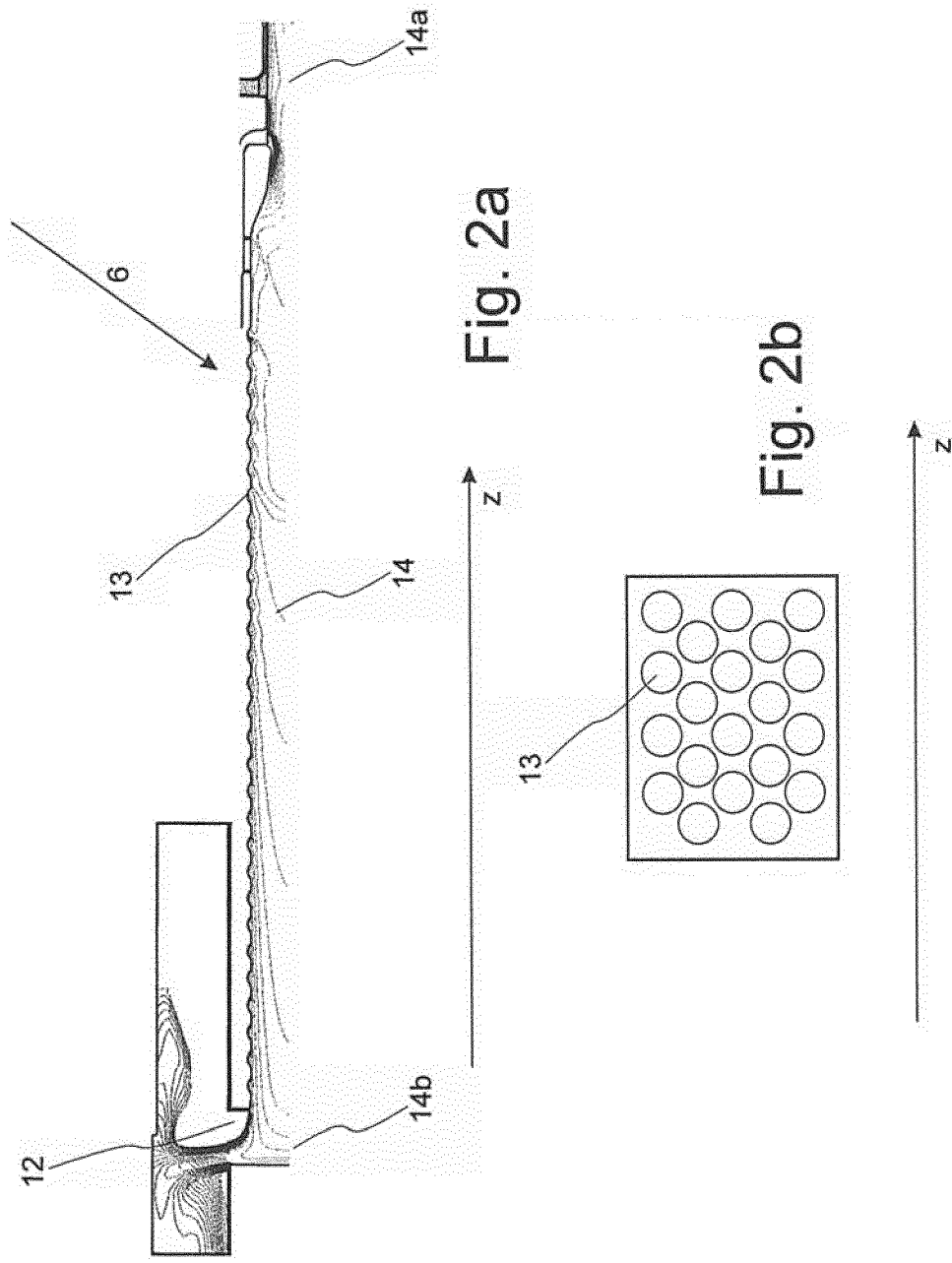


Fig. 1



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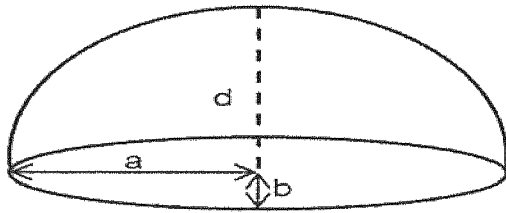


Fig. 3a

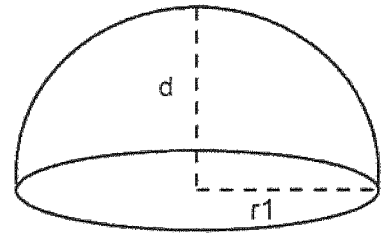


Fig. 3b

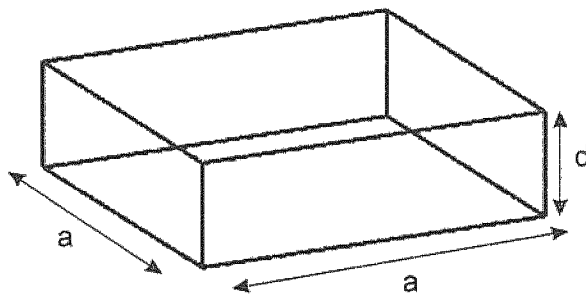


Fig. 3c

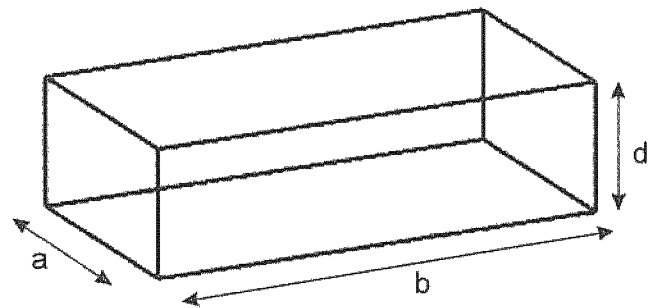


Fig. 3d

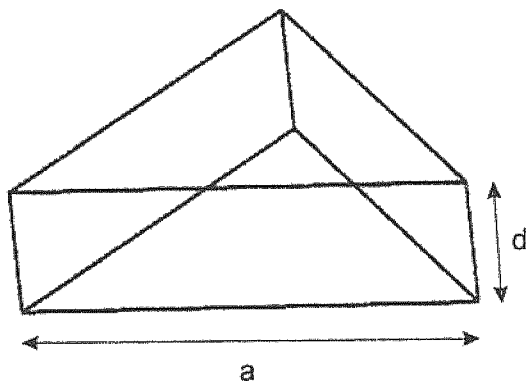


Fig. 3e

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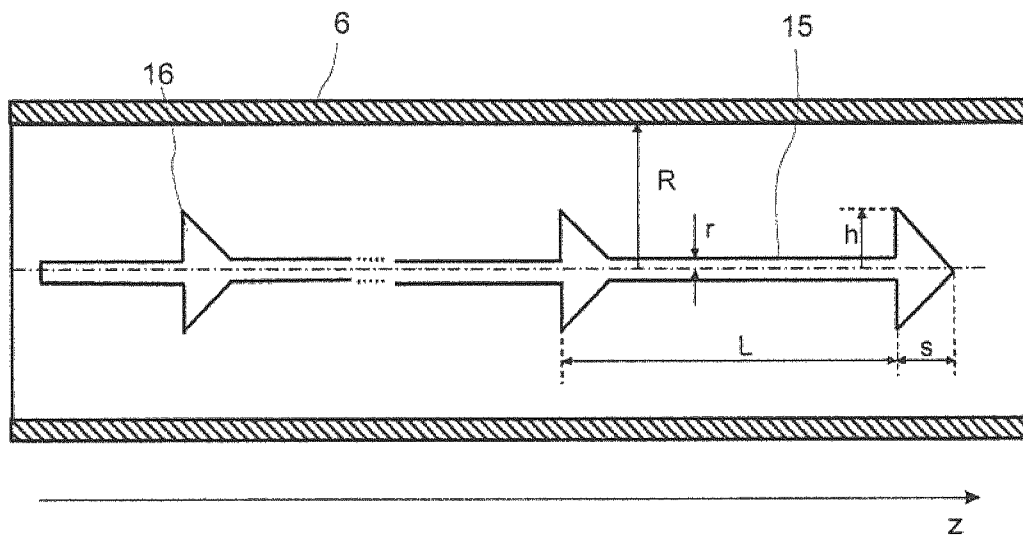


Fig. 4

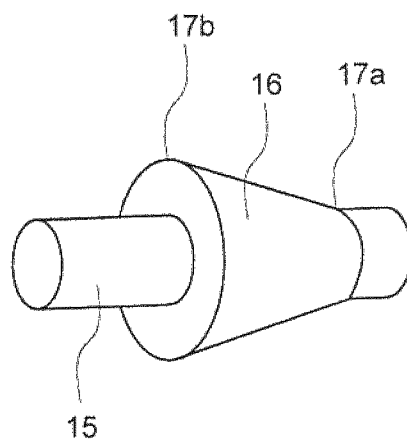


Fig. 5a

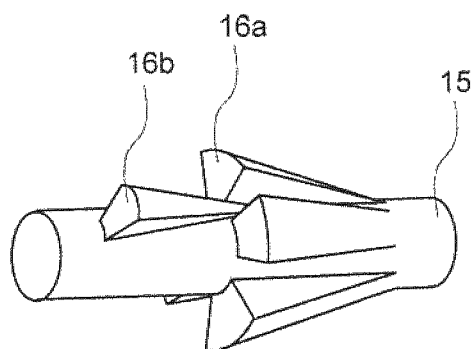


Fig. 5b

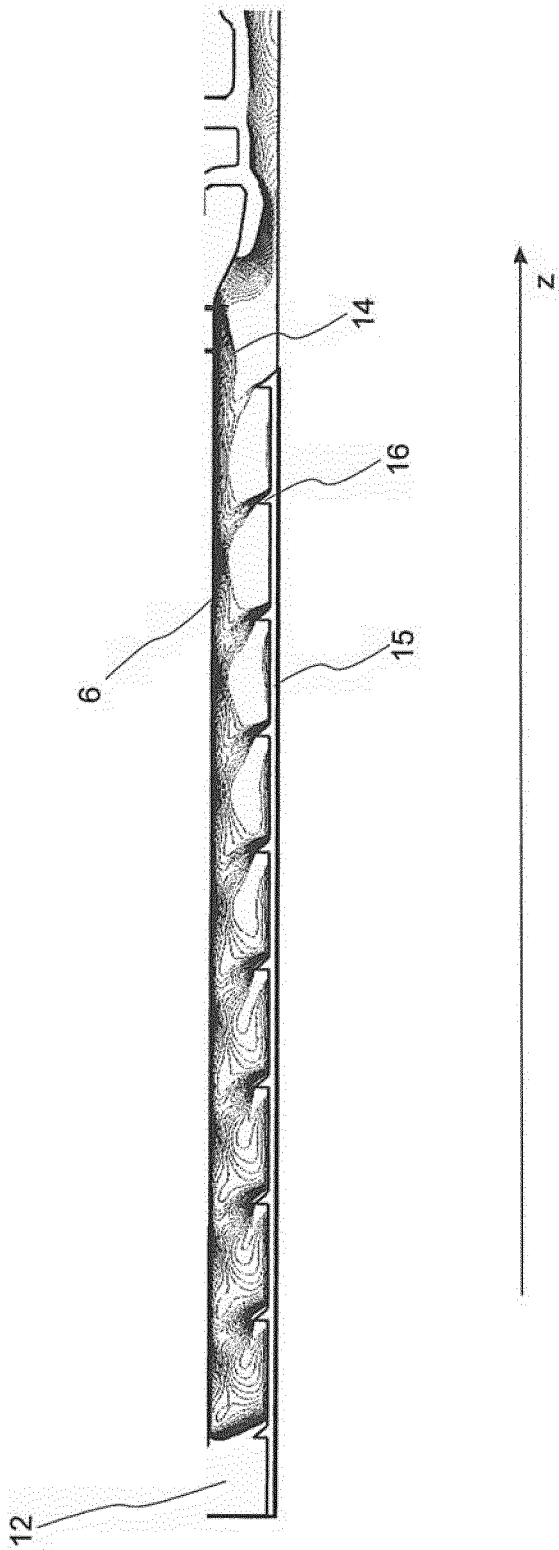


Fig. 6

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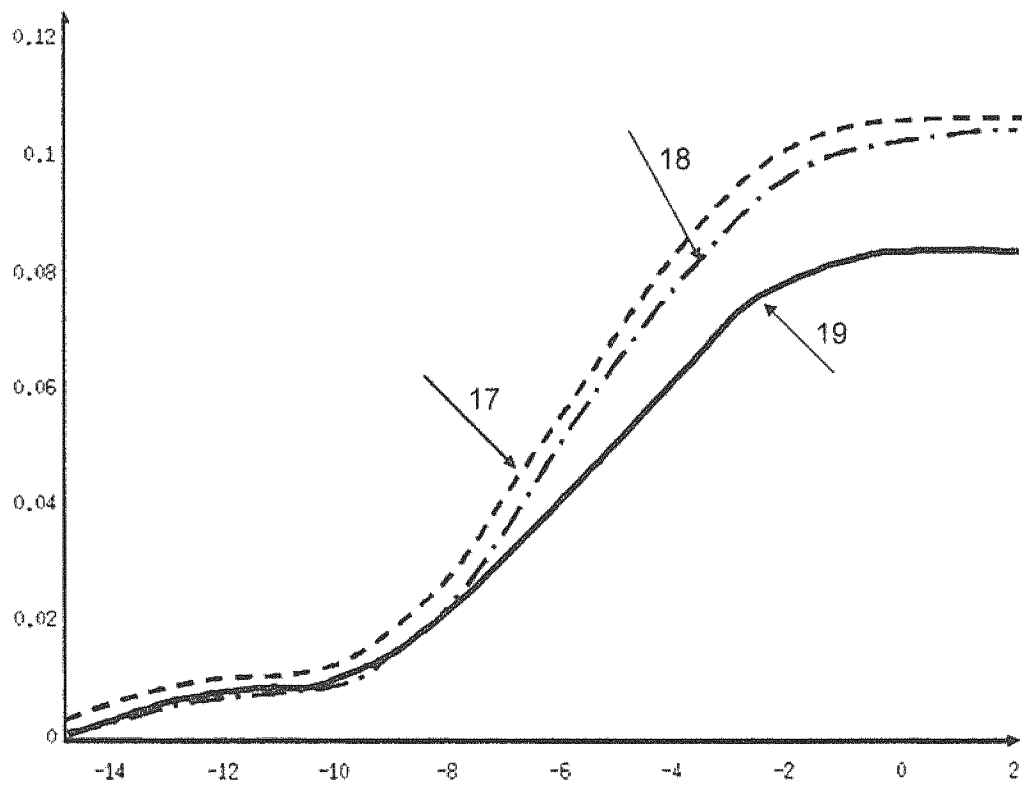


Fig. 7

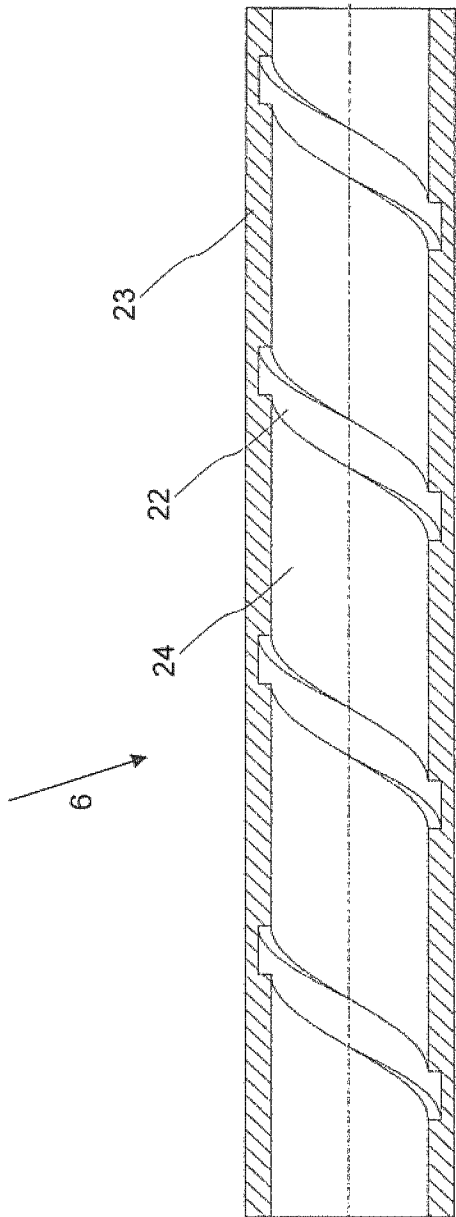


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2013/077958

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01H33/91

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 297 19 274 U1 (SIEMENS AG [DE])	1,9,10,
Y	2 January 1998 (1998-01-02)	16-22
	page 2, line 25 - line 29	3-8,11,
	page 4, line 20 - page 5, line 16	13-15,
	figures 1-3	23-29,
A	page 3, line 23 - line 25	32-37
	-----	2,12
	-/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

31 March 2014

Date of mailing of the international search report

07/04/2014

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Fribert, Jan

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2013/077958

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2005 008098 A1 (TMT & D CORP TOKYO TOKIO [JP] TOSHIBA KK [JP]) 22 September 2005 (2005-09-22) cited in the application	30,31, 38,39
Y	paragraph [0001] - paragraph [0007]	3-8,11,
	paragraph [0052]	13-15,
	paragraph [0055]	23-29,
	paragraph [0057]	32-37
A	paragraph [0062]	2,12
	paragraph [0097]	
	paragraph [0082]	
	figures 1, 7-12, 14	
	paragraph [0074]	
	paragraph [0103] - paragraph [0104]	

A	US 5 057 655 A (KERSUSAN JEAN-PIERRE [FR] ET AL) 15 October 1991 (1991-10-15) column 1, line 41 - line 56 figures 1-6 -----	1-25

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International application No

PCT/EP2013/077958

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