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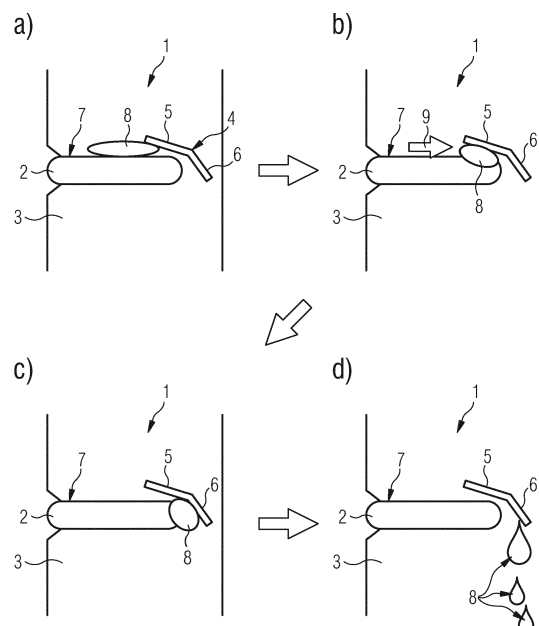
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(54) **HEAT EXCHANGER WITH GUIDING PLATES FOR CONDENSED WATER**

(57) The invention relates to a heat exchanger (1), comprising a plurality of flat tubes (2) arranged in a first row in a main extension plane of the heat exchanger (1), the flat tubes (2) having a respective main extension plane and being configured to conduct a heat transfer medium, a plurality of plate fins (3) arranged in a second row in the main extension plane of the heat exchanger (1), where the second row extends in a direction transverse to the direction of the first row, and a plurality of guiding structures (4) for guiding condensed water (8) off the tubes (2), where each guiding structure (4) extends between two plate fins (3) along a corresponding tube (2), wherein each guiding structure (4) comprises at least a first guiding plate (5) with a first main extension plane and a second guiding plate (6) with a second main extension plane, where the first main extension plane is tilted with respect to the main extension plane of the flat tube (2) around a longitudinal axis of the flat tube (2) by a first tilt angle α_1 , and the second main extension plane is tilted with respect to the main extension plane of the flat tube (2) around the longitudinal axis of the flat tube (2) by a second tilt angle α_2 , with $0 \text{ degrees} < \alpha_1 < \alpha_2 < 90 \text{ degrees}$, in order to provide a heat exchanger (1) with improved performance, in particular less problems with

condensed water (8).

FIG 1



Description

[0001] The invention relates to a heat exchanger, comprising a plurality of flat tubes arranged in a first row in a main extension plane of the heat exchanger, the flat tubes having a respective main extension plane and being configured to conduct a heat transfer medium, a plurality of plate fins arranged in a second row in the main extension plane of the heat exchanger, where the second row extends in a direction transverse to the direction of the first row, and a plurality of guiding structures for guiding condensed water off the tubes, where each guiding structure extends between two plate fins along a corresponding tube.

[0002] In air conditioners, heat exchangers are used in order to exchange heat between fluid inside tubes and air outside tubes. Several fins are provided around tubes in order to enhance the heat transfer. Conventionally, a fin and tube type, which is a combination of plate-like fins which are arranged parallel to one another in a horizontal direction and round or flat tubes which are arranged parallel to each other in a perpendicular direction, is used as a heat exchanger of an air conditioner.

[0003] On the heating operation of the air conditioner, heat transfer surfaces of a heat exchanger operate below the dew point of the airflow so that condensate water and frost can agglomerate on the surfaces. The condensate remains on the surfaces until removed by forces of surface tension, gravity, or a preparation process by off-cycle operation. The retained condensate water and frosting can cause severe problems for the performance of the heat exchanger by reduction of heat transfer and the increment of pressure drop.

[0004] Said problems especially occur when flat tubes are used as heat transfer tubes. In comparison to circular tubes, flat tubes can improve heat exchange performance because not only the heat transfer area is increased but also the airflow resistance is decreased. Meanwhile, regarding the drainage performance, the flat tube type tends to retain water droplets and these retained water droplets tend to remain on the tube surfaces due to its cross-sectional shape more easy than compared to the circular tubes. Therefore, flat tubes have the problem that it is necessary to increase the duration of a defrosting operation, which results in causing a reduction of heating performance and comfort. Also there is a problem that frosted ice which could not be removed sufficiently has a possibility to cause damage to the heat transfer tubes.

[0005] In known documents, for instance the WO 2016/194043 A1 or the JP 2016-102593 A, protrusions are formed to provide a drainage path with the fins and prevent condensate water to freeze on the heat exchanger. However, with a configuration of the heat exchanger as described in said documents, either water droplets adhering to the protrusions re-attach to one end of the flat tube, so that the drainage is insufficient, or there is a problem that water droplets don't fall down from one side of the flat tube and tend to remain there because the

protrusions are only at one side of the flat tube.

[0006] It can hence be considered a problem to be solved by the present invention to provide a heat exchanger with improved performance, in particular less problems with condensed water.

[0007] This problem is solved by the independent claim. Advantageous embodiments are described in the dependent claims, the description, and the figures.

[0008] One aspect of the invention relates to a heat exchanger with a plurality of flat tubes arranged in a first row in a main extension plane of the heat exchanger. This main extension plane may also be referred to as heat exchanger main extension plane. Therein, the flat tubes have a respective main extension plane, the flat tube main extension planes, and are configured to conduct a heat transfer medium in a conduction direction in the main extension plane of the heat exchanger transverse to the direction of the first row. In particular, conduction direction and the direction of the first row may be perpendicular to each other. In particular, the flat tubes in the first row may be parallel to each other. Furthermore, the heat exchanger comprises a plurality of plate fins, which are arranged in a second row in the main extension plane of the heat exchanger. Therein, the second row extends in a direction transverse to the direction of the first row. In particular, first and second row are arranged perpendicular to each other. The plate fins in the second row may be parallel to each other. In addition, the heat exchanger comprises a plurality of guiding structures for guiding condensed water off the flat tubes, that is, for providing a condensed water drain. Therein, each guiding structure extends between two neighboring plate fins that, in particular, are next neighbors, along a corresponding tube or tube section. So, each guiding structure is associated with the corresponding tube or tube section and prevents condensed water from remaining on and/or dripping on the corresponding tube or tube section.

[0009] Each guiding structure comprises at least a first guiding plate with a first main extension plane and a second guiding plate with a second main extension plane. Said first and second main extension planes may also be referred to as first guiding main extension plane and second guiding main extension plane. Namely, the respective guiding plates are mainly extending in the respective main extension planes. Therein, the first main extension plane is tilted with respect to the main extension plane of the associated or corresponding flat tube, or, in case of parallel flat tubes, tilted with respect to the main extension planes of the flat tubes, around a longitudinal axis of the flat tube or flat tubes by a first tilt angle α_1 . The second main extension plane is tilted with respect to the main extension plane of the associated or corresponding flat tube, or, in case of parallel flat tubes, tilted with respect to the main extension planes of the flat tubes, around a longitudinal axis of the flat tube or flat tubes by a second tilt angle α_2 . Herein, 0 degrees, in particular 1 or 2 degrees, are smaller than the first tilt angle α_1 , which is smaller than the second tilt angle α_2 , which is smaller

than 90 degrees, in short: $0 \text{ degrees} < a1 < a2 < 90 \text{ degrees}$. Hence, the first guiding main extension plane is tilted with respect to the second guiding main extension plane. The width of the guiding structures and/or the respective guiding plates in the direction of the main extension planes of the flat tubes may, in particular, be less than 50%, preferably less than 10%, of the width of the flat tubes in their main extension planes.

[0010] In particular, in order to facilitate the drainage capability of the respective guiding structure, the distance between the first guiding plate to the flat tube in a first area of the first guiding plate is greater than in a second area of the first guiding plate which is closer to the second guiding plate than the first area. In particular, the guiding structure is arranged at a leeward side of the heat exchanger, and, advantageously, not at a windward side. Each guiding structure may comprise several first guiding plates and several second guiding plates, where the several first guiding plates are parallel to each other and/or the several second guiding plates are parallel to each other.

[0011] So, the invention is based on the idea of providing at least two inclined guiding plates, that may also be referred to as protrusions, above the flat tubes to avoid re-attachment of water droplets to the lower surface of the flat tube and retention of water droplets on the upper surface of the flat tubes. Herein, upper and lower surface refer to the relative position of the surface in the intended usage position or intended working conditions of the heat exchanger. By means of the first inclined guiding plate, water retention on the upper surface of the flat tubes is removed utilizing the capillary phenomenon caused by surface tension. Then, the second inclined guiding plate attracts the drained water from the first inclined guiding plate by means of capillary phenomena as well, so that the water attaches to the second guiding plate and moves off the first guiding plate. Finally, by means of the gravity force, the drained water attached on the second inclined guiding plate or protrusion falls down alongside the plate fins. Consequently, water droplets on the upper surface of the flat tubes can be drained automatically by capillary forces and the droplets will fall down along the side of the flat tube. Hence, by the described geometry, the retention of water on the flat tube is avoided and the duration of a defrosting operation is shortened. So, the problems with condensed water are reduced and the performance of the heat exchanger is improved.

[0012] In an advantageous embodiment, each guiding structure comprises a third guiding plate with a third main extension plane, where the third main extension plane is tilted with respect to the main extension plane of the associated or corresponding flat tube, or, in case of parallel flat tubes, tilted with respect to the main extension planes of the flat tubes, around a longitudinal axis of the flat tube or flat tubes by a third tilt angle $a3$. The third tilt angle $a3$ is bigger than the second tilt angle $a2$ and smaller than or equal to 90 degrees. In particular, the third tilt angle $a3$ may be 90 degrees. This is in particular useful for

helping a water droplet to fall down vertically based on the gravity force.

[0013] The third guiding plate gives the advantage that the corners formed between the different guiding plates may be particularly narrow (as opposed to sharp), so that a water droplets do not remain in a sharp corner between the first two guiding plates, and, at the same time, the steep angle $a3$ will help the water droplets to fall down vertically. Furthermore, a production and installation process of the guiding structure is kept simple.

[0014] In another advantageous embodiment, the difference between the first tilt angle $a1$ and the second tilt angle $a2$ and/or between the second tilt angle $a2$ the third tilt angle $a3$ is at least 2, 5, 10, or 40 degrees.

[0015] This gives the advantage of a simple production and installation process in combination with a distinct and helpful guidance to the water droplets in order to fall down vertically based on a combination of capillary and gravity forces.

[0016] In a further advantageous embodiment, the first guiding plates and/or the second guiding plates and/or the third guiding plate are flat plates, for instance simple metal sheets.

[0017] This again gives the advantage of a simple production and installation process in combination with a distinct and helpful guidance to the water droplets in order to fall down vertically based on a combination of capillary and gravity forces.

[0018] In yet another embodiment, the first and second guiding plate and/or the second and third guiding plate are joined to each other. For instance, this may be realized by a single bent plate, where the two guiding plates are joined to each other in the corner of the bent plate.

[0019] This gives the advantage of an improved guidance to water droplets, as the water droplets slide down along the two guiding plates due to a capillary force which is caused by surface tension. A continuous provision of the surface tension, which is guaranteed by the joint guiding plates, is advantageous in order to keep the droplet on sliding smoothly and avoid a stop of motion of the water droplet.

[0020] In a different advantageous embodiment, the first and second guiding plate and/or the second and third guiding plate are separated from each other by a gap. In particular, the gap is small enough so that a water droplet of a given size hanging at an edge of the first or second guiding plate touches the second or third guiding plate respectively.

[0021] This gives the advantage that the problem that might occur with joint guiding plates is avoided, where a water droplet may remain at the joint corner if an initial inertial force is smaller than the surface tension. Therefore, by the gap, water droplets are prevented from remaining in such a corner due to a decreased surface tension. Conversely, if the inertial force is larger than the surface tension, there is no particular problem because, due to the inertial force, the water droplet will slide smoothly even across the gap.

[0022] Joint and separate guiding plates may also be combined. For instance, first and second guiding plate may be joint and a gap may separate second and third guiding plate, or first and second guiding plate may be separated by a gap and second and third guiding plate may be joint.

[0023] In another advantageous embodiment, the distance between the first guiding plate and the closest, that is, the corresponding flat tube allows the capillary effect to force condensed water on the tube, in particular on the upper side of the tube, to move towards the second guiding plate.

[0024] This gives the advantage that water on the tube is removed automatically due to the capillary effect without the necessity for any further actions or devices or structures.

[0025] In a further advantageous embodiment, in the intended working condition or intended usage, the main extension plane of the flat tube (or flat tubes in case of parallel flat tubes), is the horizontal plane. Accordingly, in this intended working condition, the main extension plane of the heat exchanger may be a vertical plane perpendicular to the horizontal plane.

[0026] This gives the advantage that capillary and gravitational forces are particularly suitable for draining the water from the tubes.

[0027] In another advantageous embodiment, an orthogonal projection of the first guiding plate onto the second main extension plane as well as an orthogonal projection of the second guiding plate onto the first main extension plane does overlap with the second guiding plate, or the first guiding plate, respectively, to an extent of less than 5%, preferably less than 1% or not at all, and/or an orthogonal projection of the second guiding plate onto the third main extension plane as well as an orthogonal projection of the third guiding plate onto the second main extension plane does overlap with the third guiding plate, or the second guiding plate, respectively, to an extent of less than 5%, preferably less than 1% or not at all.

[0028] This gives the advantage that water drops can be removed or drained from the tube with particularly high efficiency as the guiding plates cover a wide area of the tubes.

[0029] The features and combinations of features described above, as well as the features and combinations of features disclosed in the figure description or the figures alone may not only be used alone or in the described combination, but also with other features or without some of the disclosed features without leaving the scope of the invention. Consequently, embodiments that are not explicitly shown and described by the figures but that can be generated by separately combining the individual features disclosed in the figures are also part of the invention. Therefore, embodiments and combinations of features that do not comprise all features of an originally formulated independent claim are to be regarded as disclosed. Furthermore, embodiments and combinations of

features that differ from or extend beyond the combinations of features described by the dependencies of the claims are to be regarded as disclosed.

[0030] Exemplary embodiments are further described in the following by means of schematic drawings. Therein,

Fig. 1 shows a first exemplary embodiment of a heat exchanger;

Fig. 2 shows an additional view on the first embodiment; and

Fig. 3 shows a second exemplary embodiment of a heat exchanger.

[0031] In the figures, identical or functionally identical elements have the same reference signs.

[0032] Figure 1 shows a first exemplary embodiment of a heat exchanger and illustrates the working principle of a guiding structure with at least two guiding plates in sections a) -d). Said exemplary heat exchanger 1 comprises a plurality of flat tubes 2 in a first row and a plurality of plate fins 3 arranged in a second row. Therein, the first row and the second row extend in a main extension plane of the heat exchanger 1. The main extension plane of the heat exchanger 1 is arranged perpendicular to the drawing plane of figure 1, where the first row extends in the drawing plane and the second row extends perpendicular to the drawing plane. The flat tubes 2 have a longitudinal direction that extends perpendicular to the drawing plane and a main extension plane that extends perpendicular to the drawing plane. In the example presented, first and second row are arranged perpendicular to each other. For the sake of simplicity, only a part of the heat exchanger one comprising one single flat tube 2 and one single plate fin 3 is shown in figure 1. Accordingly, only one of the plurality of guiding structures 4 that are used to guide condensed water off the tubes 2, wear each guiding structure for extends between two plate fins 3 along a corresponding tube 2 is shown in figure 1.

[0033] In the present example, the guiding structure for comprises a first guiding plate 5 with a first main extension plane perpendicular to the drawing plane and a second guiding plate 6 with a second main extension plane arranged perpendicular to the drawing plane, as well. Therein, the first main extension plane of the first guiding plate 5, the first guiding main extension plane, is tilted with respect to the main extension plane of the flat tube 2 to around a longitudinal axis or direction of the flat tube 2 in which direction the heat transfer medium is conducted by a first tilt angle α_1 (Fig. 2). The second main extension plane of the second guiding plate 6, the second guiding main extension plane, is tilted with respect to the main extension plane of the flat tube 2 around the longitudinal axis or direction of the flat tube 2 in which direction the heat transfer medium is conducted by a second tilt angle α_2 (Fig. 2). For the two tilt angles α_1 , α_2 , the fol-

lowing relation holds: $0 \text{ degrees} < a1 < a2 < 90 \text{ degrees}$.

[0034] So, the two guiding plates 5, 6 are tilted by first and second tilt angle $a1$, $a2$ with respect to an upper surface 7 of the flat tube 2. Preferably, the upper surface 7 extends horizontally in the intended working conditions of the heat exchanger 1, i.e. in operation of the heat exchanger 1. Consequently, a water droplet 8 may appear or lay on the upper surface 7 during operation of the heat exchanger 1 as shown in section a) of figure 1. Said water droplet 8 is forced to move along the upper surface seven and the first guiding plate 5 into the direction of the second guiding plate 6 by capillary forces. Hence, the distance between the first guiding plate 5 and the flat tube 2, in particular the upper surface 7 of flat tube 2, is chosen such that the capillary forces necessary for the desired effect apply for a water droplet of condensed water on the effective surface structures of first guiding plate 5 and upper surface 7 in dependence of the chosen material. The capillary force is symbolized by arrow 9 in section b) of figure 1. In particular, the distance between the first guiding plate 5 and upper surface 7 decreases towards second guiding plate 6. In particular, the distance is bigger in an end area of first guiding plate 5 on the far side from second guiding plate 6 than in another area of the first guiding plate 5 closer to the second guiding plate 6.

[0035] Due to the surface tension, the water droplet aid is then moved on the first guiding plate 5 towards the second guiding plate 6 and further along the second guiding plate six as shown in section c) of figure 1. Here, and advantageous effect arises when the second guiding plate 6 is, in contrast to the end portion of the flat tube 2 close to second guiding plate 6, flat (and not curved). The water droplet 8 then moves along the second guiding plate 6 due to gravitational forces and finally falls of the second guiding plate 6 as depicted in section d) of figure 1.

[0036] Figure 2 shows an additional view on the first embodiment of Fig. 1. Here, to of the flat tubes to our shown with the respective guiding structures for. At the upper tube 2, the water droplet 8 is shown in the drainage path 10, the gap between guiding structure 4 and flat tube 2, along with two arrows 11, 12 illustrating the movement of the water droplet eight. Therein, the first arrow 11 illustrates the effect of the capillary forces, the second arrow 12 the effect of surface tension and gravitational force. At the lower tube 2 and the respective guiding structure 4, the two tilt angles $a1$, $a2$ are illustrated. It is shown that the two tilt angles $a1$, $a2$ are measured relative to the main extension plane of the flat tube 2, which is perpendicular to the drawing plane in the current example. The main extension plane of the flat tube 2 may be the horizontal plane in the intended working conditions of the heat exchanger 1.

[0037] Figure 3 shows a second exemplary embodiment of a heat exchanger with respective guiding structures. In the present example, in addition to the first guiding plate 5 and the second guiding plate 6, a third guiding plate 11 is part of the respective guiding structures 4.

Said third guiding plate 11 has a third main extension plane, which is tilted with respect to the main extension plane of the flat tube 2 around the longitudinal axis of the flat tube 2 by a third tilt angle $a3$, similar to the first and second guiding plates 5, 6. The third tilt angle $a3$ fulfils the condition $a2 < a3 \leq 90 \text{ degrees}$. In the present example, the third tilt angle $a3$ equals 90° . In contrast to the first embodiment shown in figures 1 and 2, in the present embodiment, the guiding plates 5, 6, 11 are not joint, but separated by respective gaps 12, 13. The first 12 is the gap between first guiding plate 5 and second guiding plate 6, and the second gap 13 is the gap between the second guiding plate 6 and third guiding plate 11.

[0038] At the upper flat tube 2 in the drawing, the behavior of the water droplet 8 is depicted. As in the first embodiment, the water droplet is moved along the first guiding plate 5 towards the second guiding plate 6 by capillary forces. At the end of the first guiding plate 5, as the gap first 12 is small enough to allow surface forces to draw the water droplet 8 towards the second guiding plate 6 and further along it. The water droplet 8 continues to move along the second guiding plate 6, and is not stopped by the first gap 12. The first gap 12 allows to choose the tilt angles $a1$, $a2$ more freely, as a narrow corner, where, in an undesired scenario, the water droplet 8 might stop its movement and remain there, is avoided. This applies, mutatis mutandis, to the second gap 13. Accordingly, only one of the two gaps 12, 13 might be sufficient for the drainage of the water droplet 8 when the tilt angles $a1$, $a2$, $a3$ are chosen, in dependence of the surface structure of the guiding plates, such that the water droplet 8 will not stop in the corner between the respective guiding plates 5, 6, 11.

[0039] At the lower flat tube 2 and guiding structure 4, the respective angles $a1$, $a2$, $a3$ are illustrated. Again, the tilt angles $a1$, $a2$, $a3$ can be used to describe the slope or inclination of the respective guiding plates 5, 6, 11 with respect to the surface 7 of the flat tube 2, which might extend along the horizontal axis when the heat exchanger 1 is in operation.

Claims

1. A heat exchanger (1), comprising

- a plurality of flat tubes (2) arranged in a first row in a main extension plane of the heat exchanger (1), the flat tubes (2) having a respective main extension plane and being configured to conduct a heat transfer medium;
- a plurality of plate fins (3) arranged in a second row in the main extension plane of the heat exchanger (1), where the second row extends in a direction transverse to the direction of the first row;
- a plurality of guiding structures (4) for guiding condensed water (8) off the tubes (2), where

- each guiding structure (4) extends between two plate fins (3) along a corresponding tube (2); **characterized in that**
- each guiding structure (4) comprises at least a first guiding plate (5) with a first main extension plane and a second guiding plate (6) with a second main extension plane, where
 - the first main extension plane is tilted with respect to the main extension plane of the flat tube (2) around a longitudinal axis of the flat tube (2) by a first tilt angle α_1 ; and
 - the second main extension plane is tilted with respect to the main extension plane of the flat tube (2) around the longitudinal axis of the flat tube (2) by a second tilt angle α_2 ;
 - with $0 \text{ degrees} < \alpha_1 < \alpha_2 < 90 \text{ degrees}$.
2. The heat exchanger (1) of claim 1, **characterized in that** each guiding structure (4) comprises a third guiding plate (11) with a third main extension plane, where the third main extension plane is tilted with respect to the main extension plane of the flat tube (2) around the longitudinal axis of the flat tube (2) by a third tilt angle α_3 , with $\alpha_2 < \alpha_3 \leq 90 \text{ degrees}$.
3. The heat exchanger (1) of claim 2, **characterized in that** the third tilt angle α_3 is 90 degrees.
4. The heat exchanger (1) of any of the preceding claims, **characterized in that** the difference between the first tilt angle α_1 and the second tilt angle α_2 and/or between the second tilt angle α_2 and the third tilt angle α_3 is at least 2, 5, 10, 20, or 40 degrees.
5. The heat exchanger (1) of any of the preceding claims, **characterized in that** the first guiding plate (5) and/or the second guiding plate (6) and/or the third guiding plate (11) are flat plates.
6. The heat exchanger (1) of any of the preceding claims, **characterized in that** the first and second guiding plates (5, 6) and/or the second and third guiding plates (6, 11) are joined to each other.
7. The heat exchanger (1) of any of the claims 1 to 5, **characterized in that** the first and second guiding plates (5, 6) and/or the second and third guiding plates (6, 11) are separated from each other by a gap.
8. The heat exchanger (1) of any of the preceding claims, **characterized in that** the distance between the first guiding plate (5) and the closest flat tube (2) allows the capillary effect to force condensed water (8) on the tube (2) to move towards the second guiding plate (6).
9. The heat exchanger (1) of any of the preceding claims, **characterized in that**, in the intended working conditions, the main extension plane of the flat tube (2) is the horizontal plane.
10. The heat exchanger (1) of any of the preceding claims, **characterized in that** an orthogonal projection of the first guiding plate (5) on the second main extension plane does overlap with the second guiding plate (6) to an extent of less than 5%, preferably less than 1% or not at all, and/or an orthogonal projection of the second guiding plate (6) on the third main extension plane does overlap with the third guiding plate (11) to an extent of less than 5%, preferably less than 1% or not at all.

FIG 1

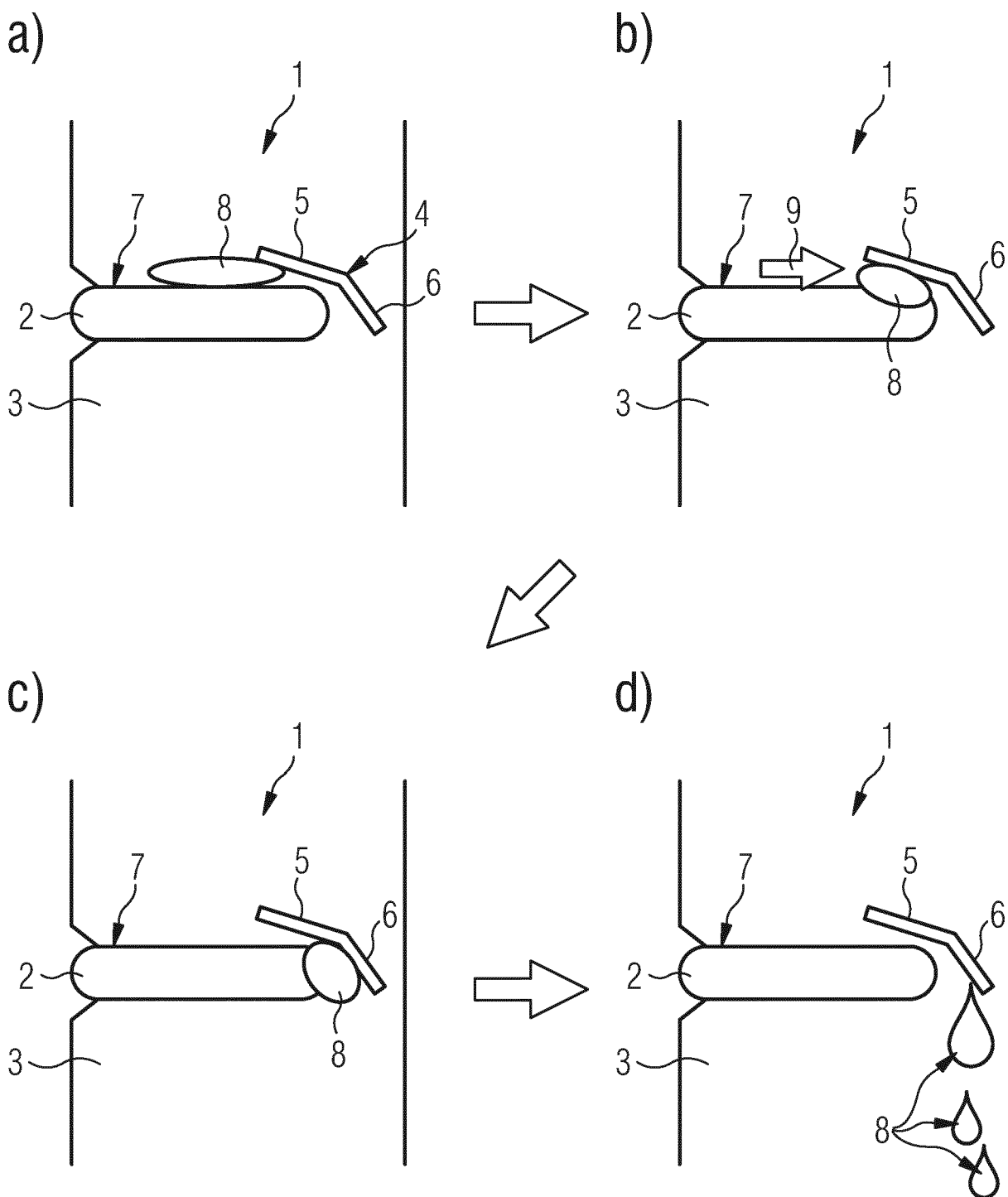


FIG 2

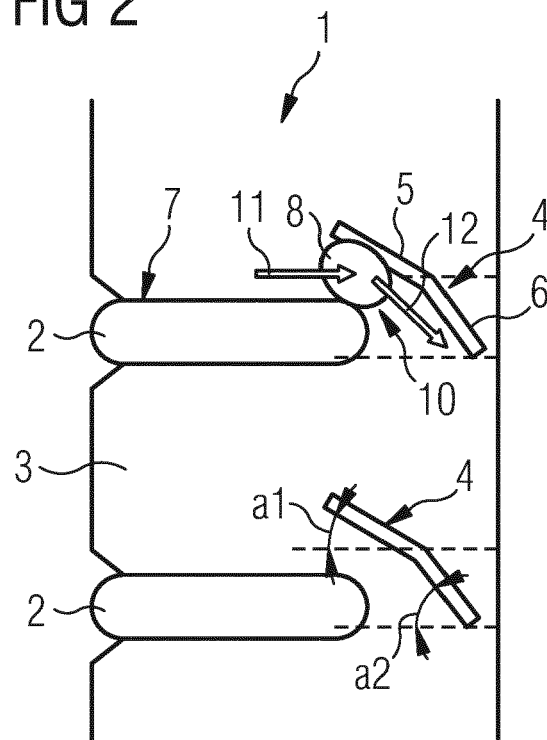
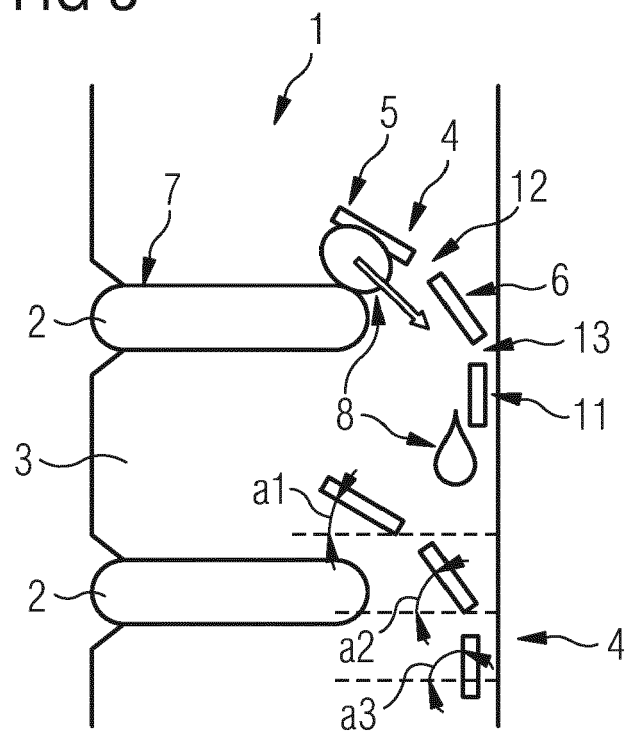


FIG 3





EUROPEAN SEARCH REPORT

Application Number
EP 18 16 3856

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 September 2018	Examiner Martínez Rico, Celia
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 18 16 3856

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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19-09-2018

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