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(54) **HEAT EXCHANGER DEVICE**

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(57) **ABSTRACT**

A multilayer heat exchanger device comprises: a stack of double sided plates arranged to provide multiple fluid flow paths separated by the plates; wherein the double sided plates each have an array of heat exchanger fins extending outward from both sides of a body of the plate into the fluid flow paths on either side of the plate; and wherein outer ends of the fins of the double sided plates are bonded on each side of the plates to the fins, or between the fins, of the adjacent plates. The double sided plates may be manufactured by etching.

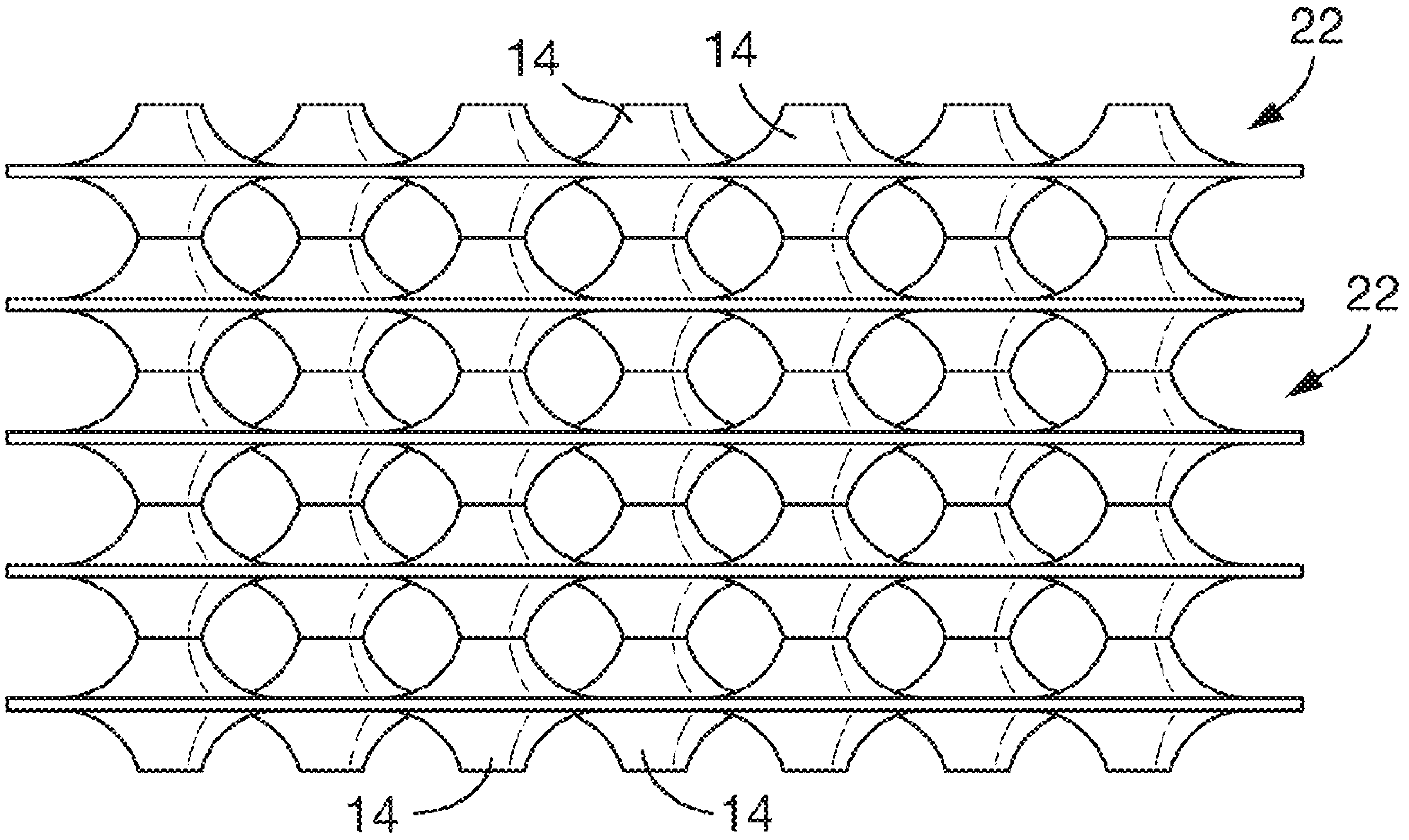


Fig. 1

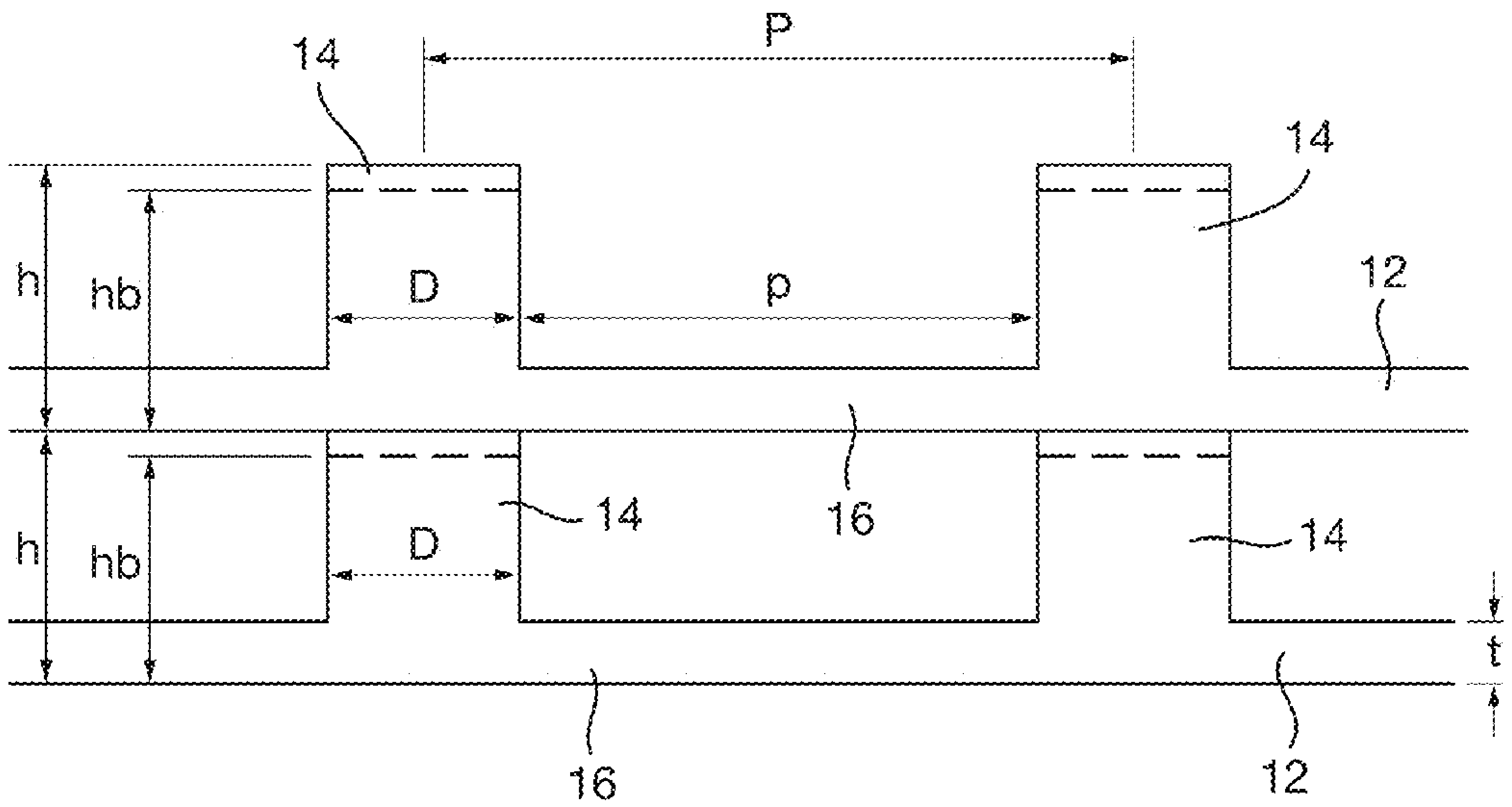


Fig. 2

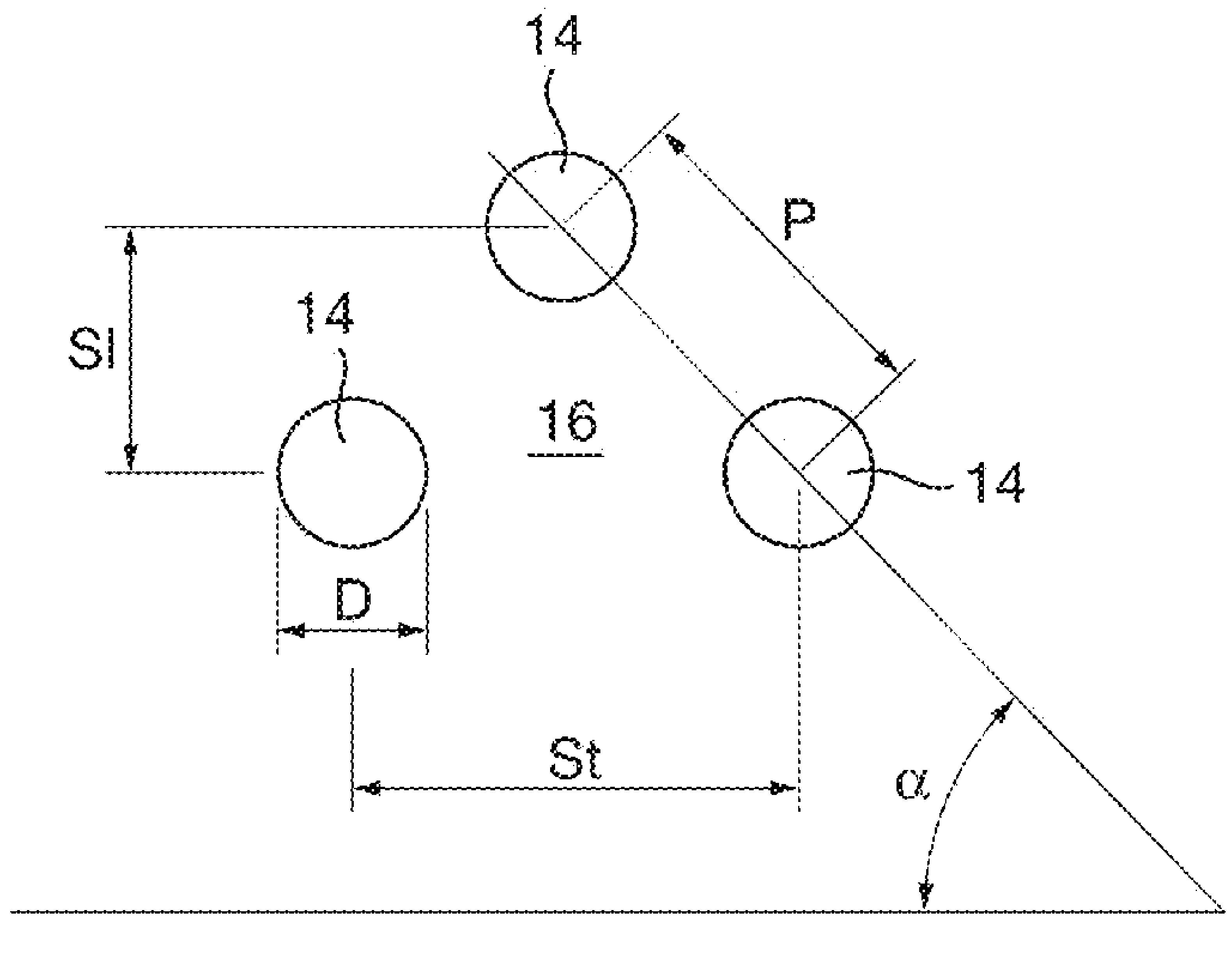


Fig. 3

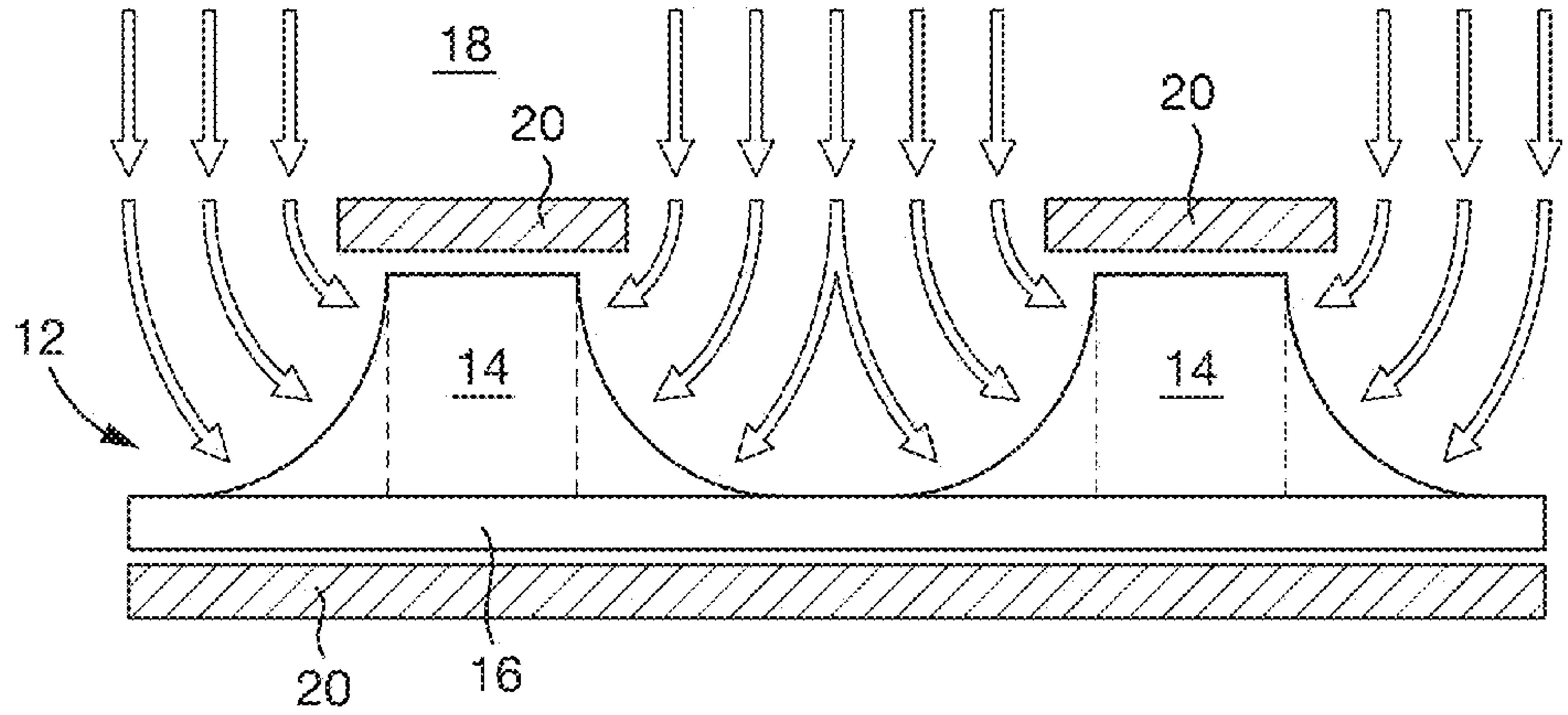


Fig. 4

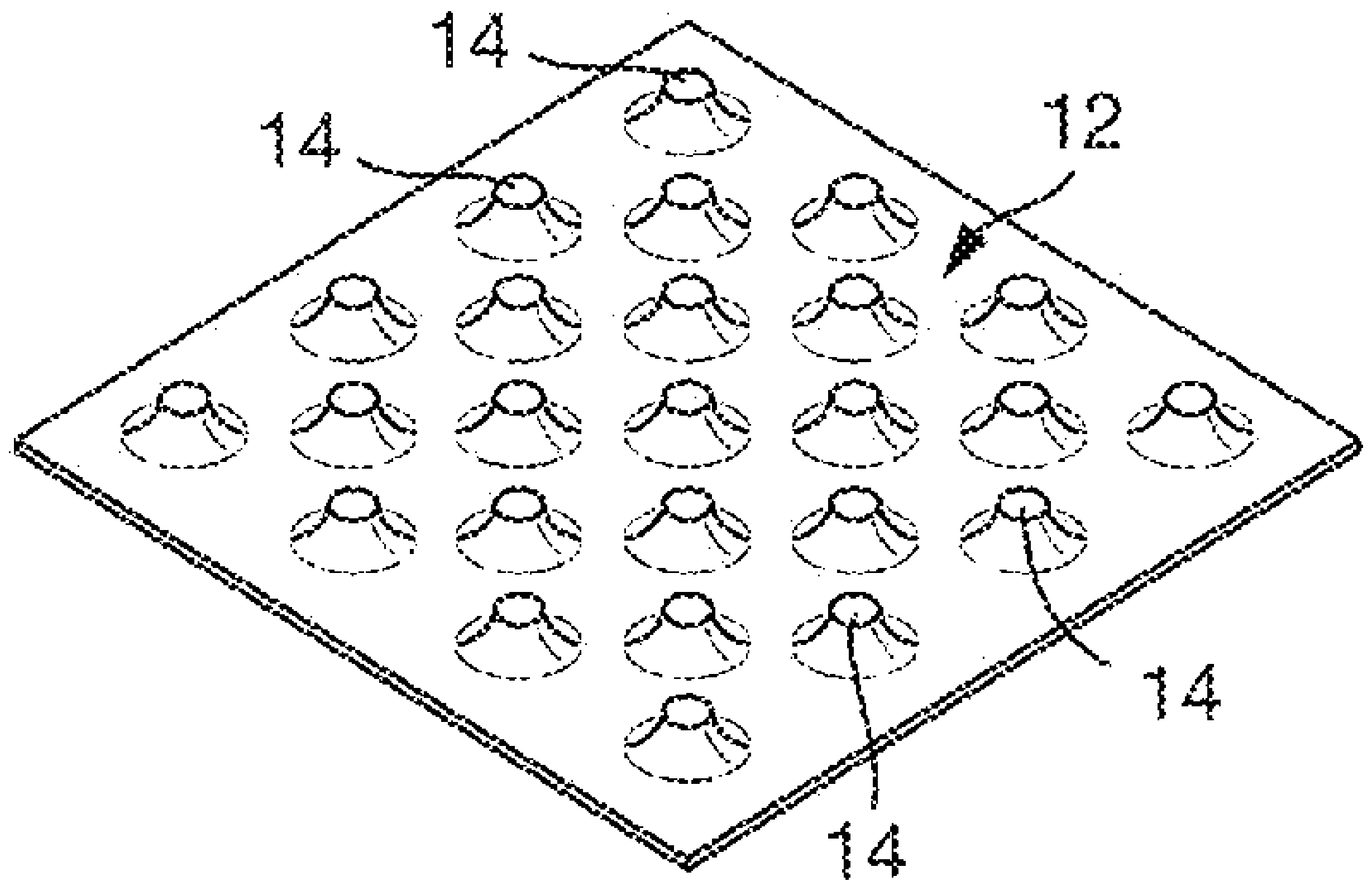


Fig. 5

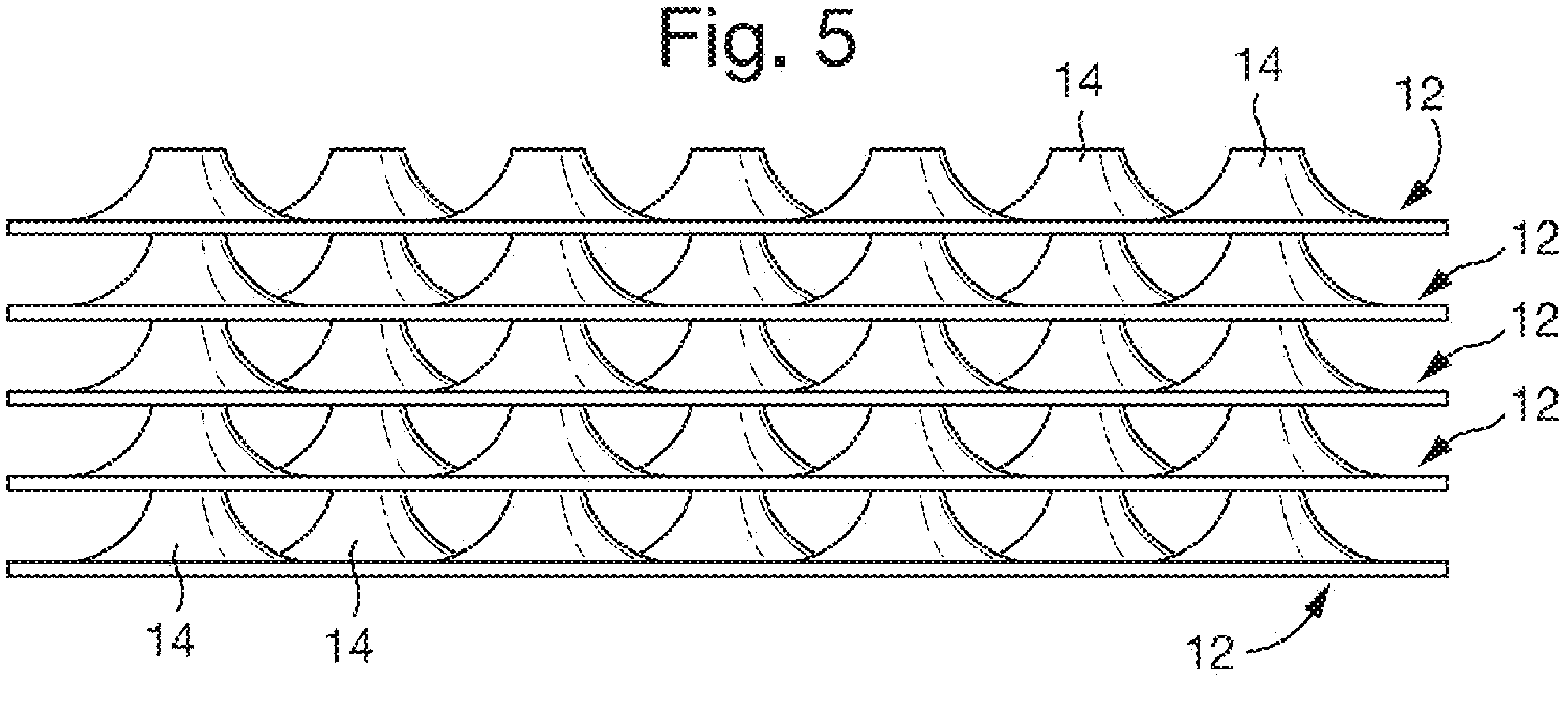


Fig. 6

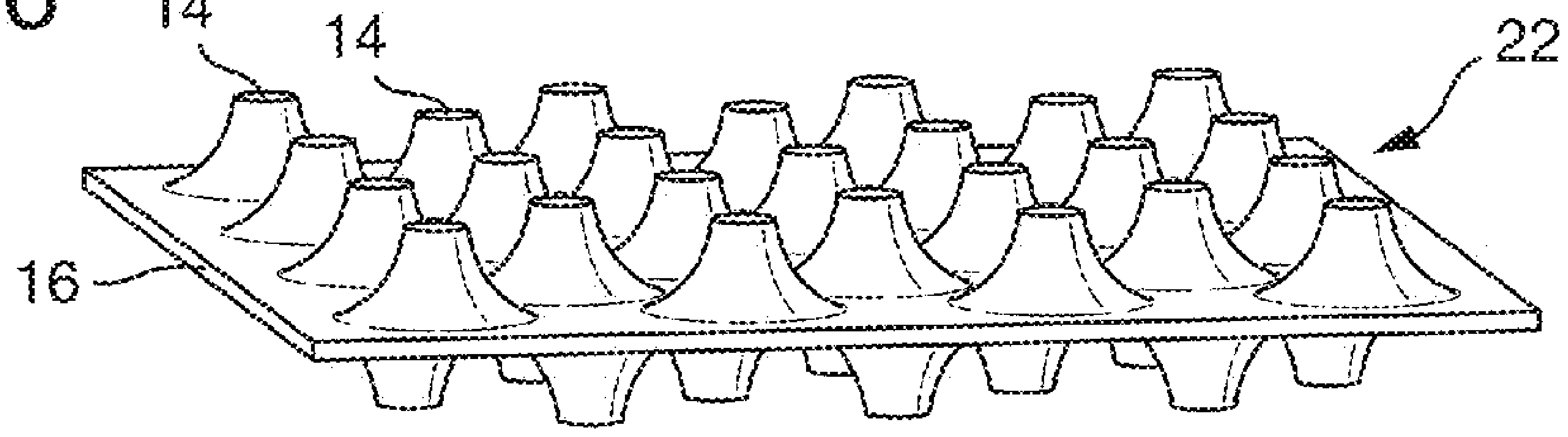


Fig. 7

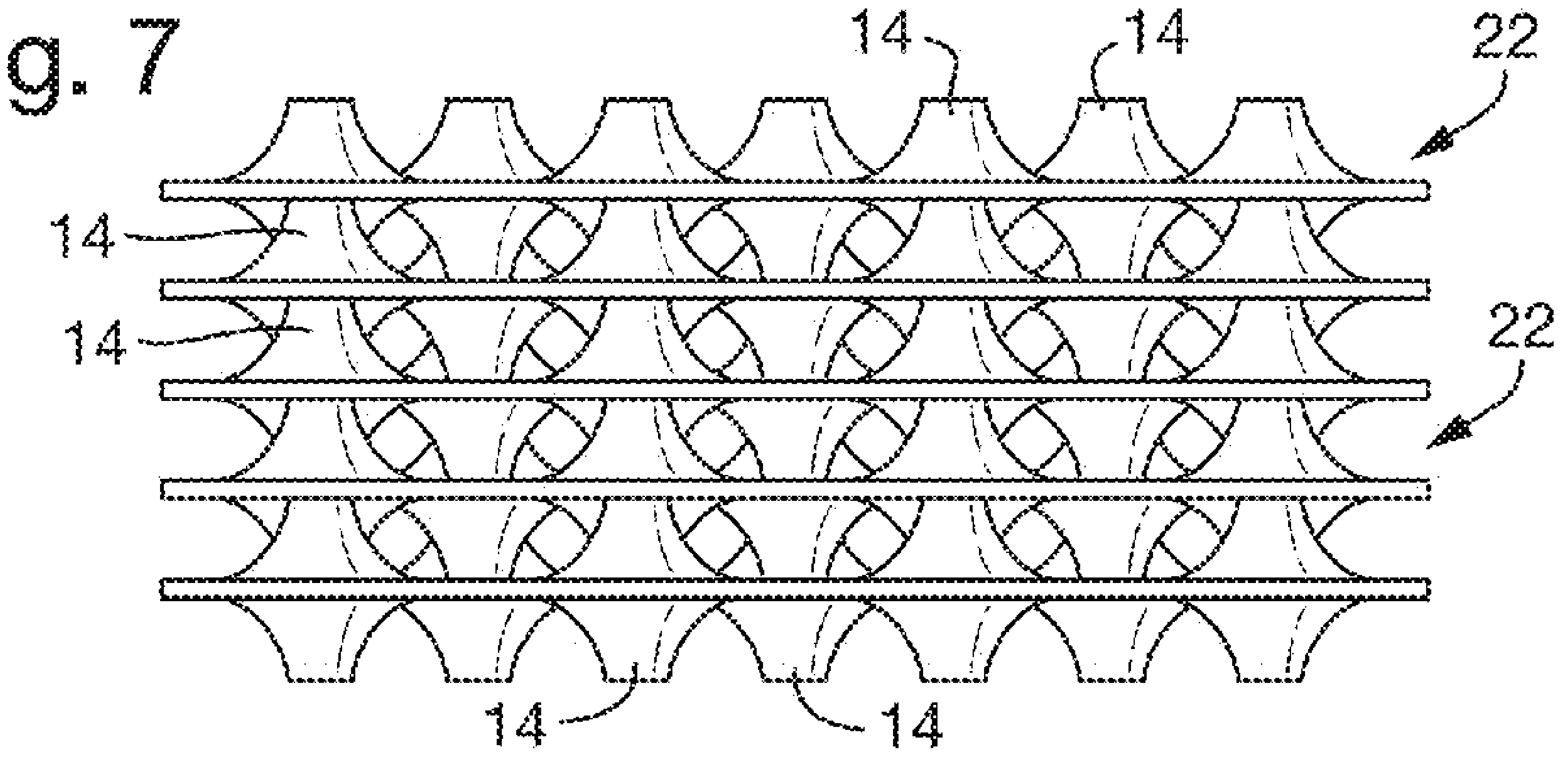


Fig. 8

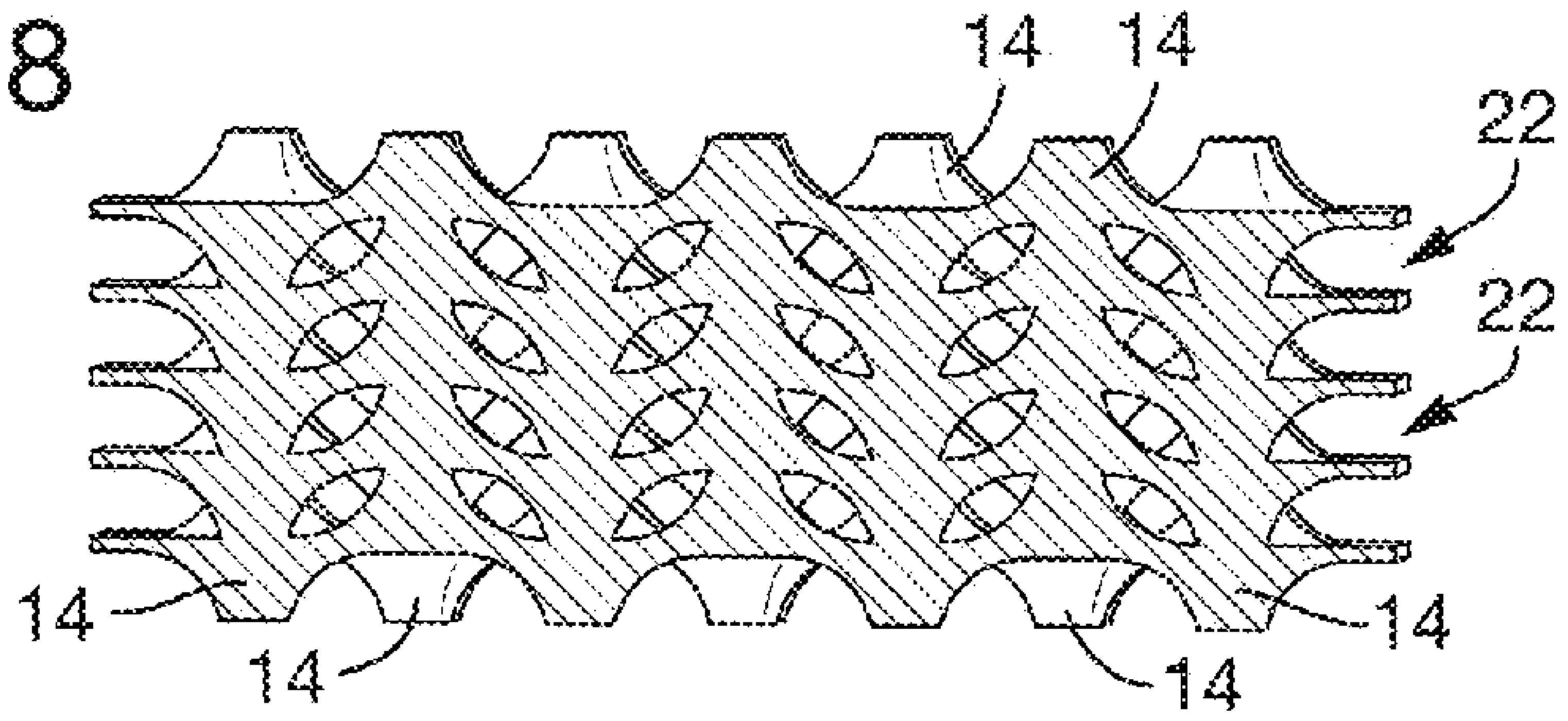


Fig. 9

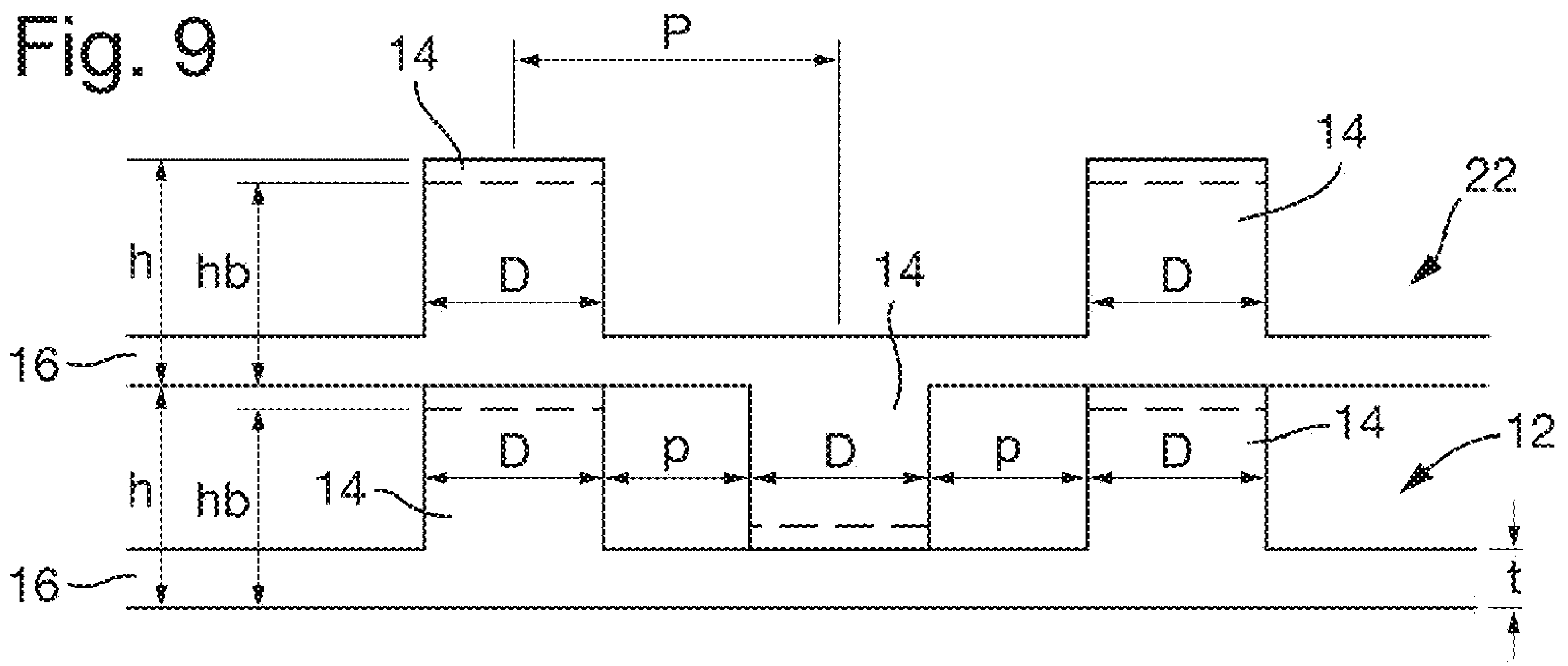


Fig. 10

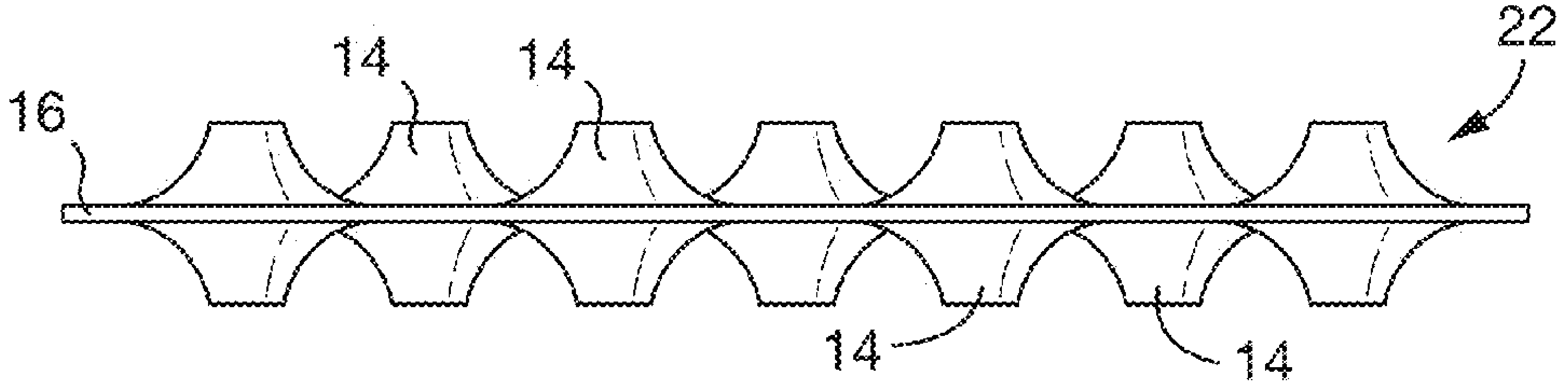


Fig. 11

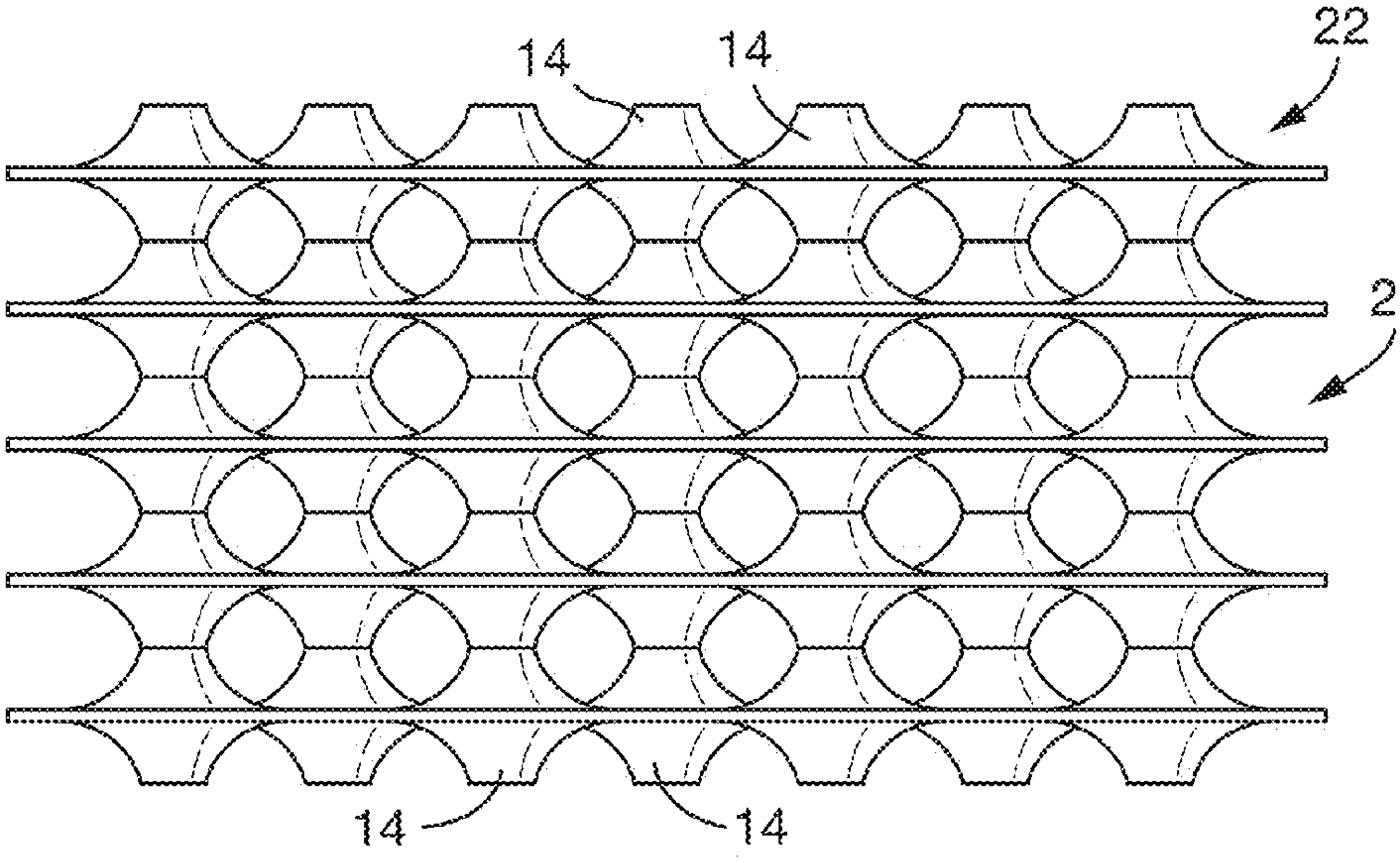
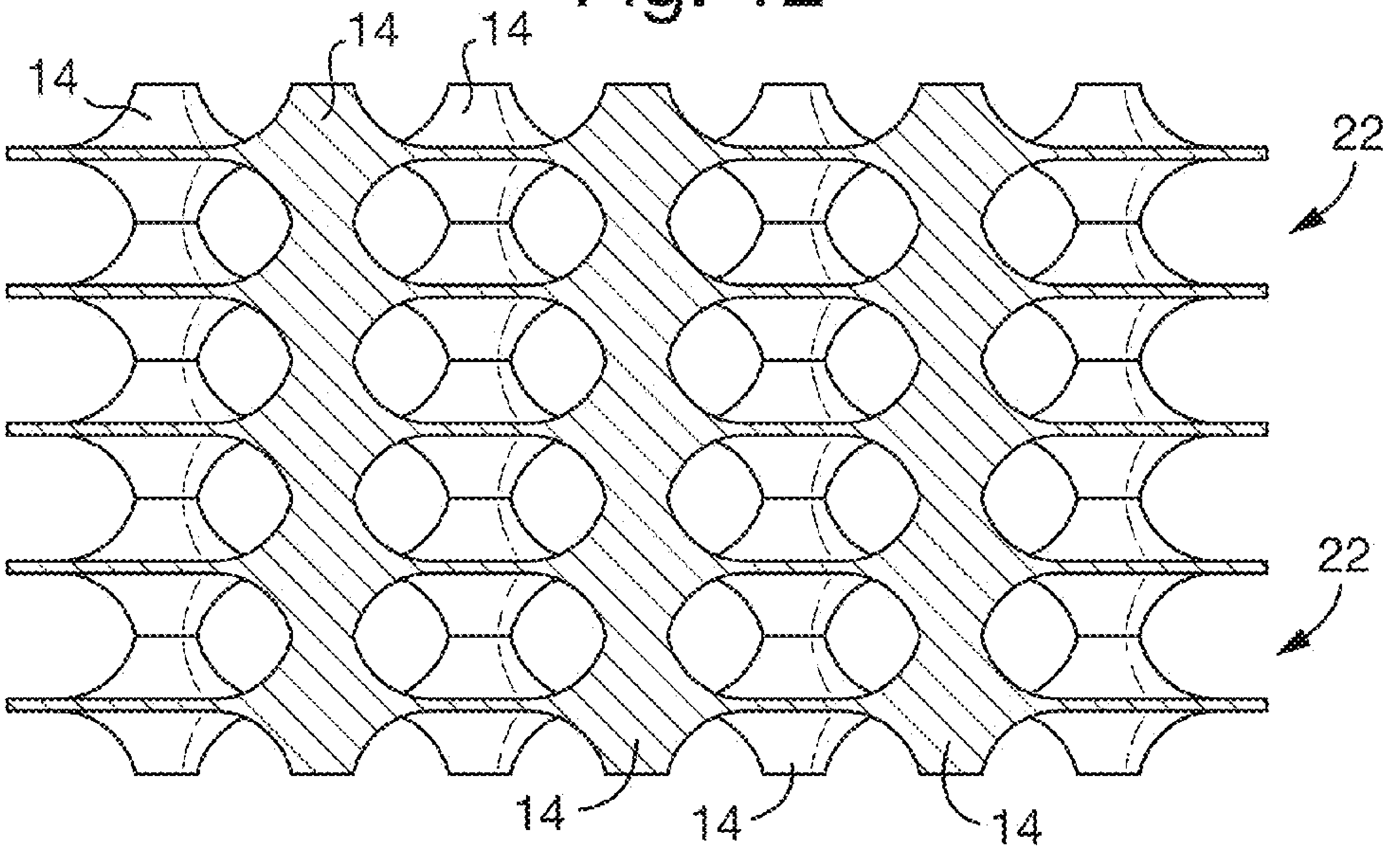


Fig. 12



HEAT EXCHANGER DEVICE

FOREIGN PRIORITY

[0001] This application claims priority to Great Britain Patent Application No. 1613918.0 filed Aug. 15, 2016, the entire contents of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] The invention relates to a heat exchanger device and to a method for manufacturing a heat exchanger device. In an example implementation the heat exchanger device is for aerospace use.

[0003] Heat exchangers for transfer of heat between different fluids are very widely used and exist in various forms. Typically heat exchangers are arranged for flow of a primary fluid and a secondary fluid with heat being transferred between the two fluids as they flow through the device. Multi-stream heat exchangers for exchanging heat between more than two fluids also exist in the prior art. Some heat exchangers have a layered structure with a large number of parallel flow paths between plates that separate the flow paths. There may be 50-200 plates, or more, in this type of heat exchanger, typically with alternating hot/cold fluid flow paths either side of each plate. Such heat exchangers can also be referred to as laminate heat exchangers.

[0004] The plates generally have features to promote heat transfer and/or turbulent flow of the fluids, such as protrusions extending outward from the body of the plates into the flow of fluid. These features are referred to generally as fins, which includes various geometries of fins forming chambers within the flow passages, such as straight-finned triangular or rectangular arrangements; herringbone, where the fins are placed sideways to provide a zig-zag path; serrated and/or perforated fins, which include cuts and perforations in the fins to augment flow distribution and improve heat transfer; as well as pin fins, where the fins are columnar shapes extending outward from the body of the plates, typically normal to the plane of the plates.

[0005] U.S. Pat. No. 8,616,269 discloses an example of a pin fin heat exchanger device with multiple layers. Multiple double sided plates are arranged in a stack with spaces between surfaces of the plates and adjacent plates enclosing fluid flow paths for a first fluid and a second fluid. Pins extend from one or both sides of the plates toward the adjacent plate(s), so that the pins extend into the fluid flow paths. The pins can be formed separately to the plates and mounted to the plates. In particular, the pins are inserted through the plates using through holes. Alternatively the pins can be formed integrally with the plate or plates by chemical etching. The pins can pass through multiple plates. In some cases the pins extending from one plate may have their ends facing the ends of pins extending from the adjacent plate, in which case the heat exchanger device of U.S. Pat. No. 8,616,269 is formed with a gap between the pin ends.

SUMMARY

[0006] Viewed from a first aspect, the invention provides a multilayer heat exchanger device comprising: a stack of double sided plates arranged to provide multiple fluid flow paths separated by the plates; wherein the double sided plates each have an array of heat exchanger fins extending outward from both sides of a body of the plate into the fluid flow paths on either side of the plate; and wherein outer ends of the fins of the double sided plates are bonded on each side of the plates to the fins or between the fins of the adjacent plates.

[0007] This arrangement provides a high degree of flexibility in terms of the spacing of the fins and the spacing between the plates, whilst also ensuring that the device is strong, with a structure that can be both lightweight and stiff. In contrast to U.S. Pat. No. 8,616,269, where some or all of the fin pins have free ends, the fin ends in the above aspect are bonded to a part of the adjacent plate, which means that every layer is connected to the adjacent layer with a relatively rigid join, and with attachment points extending across the area of the plates. At least a majority of the fin ends may be bonded to the adjacent plate, optionally all of the fin ends. In addition, since the plates are double sided then unlike U.S. Pat. No. 8,616,269 the pins extend inward into the flow paths from both sides, rather than just from one side as is the case for some of the layers in U.S. Pat. No. 8,616,269. The combination of strength and low weight has particular advantages for aerospace applications, and will also have benefits in any other use for a heat exchanger where weight, strength and stiffness are beneficial properties. The bonding of the fins to the adjacent plate may also provide enhancements in the heat exchanging characteristics of the device.

[0008] A multilayer heat exchanger device of the type set out in the first aspect has many layers with multiple fluid flow paths each being arranged for heat exchange with adjacent fluid flow paths. The fluid flow paths may all be in parallel planes, and may have parallel flow paths with the same or opposed directions of flow. Thus, the plates may be generally planar in order that adjacent plates enclose a fluid flow path with the principle flow direction being parallel with the planes of the adjacent plates. A typical heat exchanger device has primary and secondary fluids flowing in parallel paths in different directions, which maximises the temperature differential between the fluids and thus gives the greatest rate of heat transfer. Such a heat exchanger device is to be differentiated from a heat sink in that heat transfer is promoted via flow of the fluid through the flow paths rather than occurring with passive convection of fluid away from the heat exchange elements as it is heated or cooled. Thus, the heat exchanger may be arranged for forced flow of fluid through the fluid flow paths, for example by being coupled via fluid inlets and outlets to incoming and outgoing fluid passages with a differential pressure. The fluid inlets and outlets may be common to multiple flow paths, for example with a first set of inlets and outlets for a first fluid and a second set of inlets and outlets for a second fluid, the first and second fluids having different temperatures at the respective inlets and heat being transferred between the first and second fluids as they flow through the heat exchanger.

[0009] The array of fins advantageously includes multiple fins distributed across the surface of the body of the plate, and these may all extend in generally the same direction from the body of the plate, for example they may all extend generally perpendicular to a surface of the body of the plate. The bodies of the plates may be generally planar and may extend across a two dimensional area of the volume of the heat exchanger device. The fins extending from either side of the double sided plate may have a similar or an identical pattern, and may be aligned with each other or may be offset from one another. Using a double sided plate with fins that are offset on either side means that multiple similar plates can be stacked in the same orientation with interleaved fins without the need to offset the bodies of the plates. An offset type plate design could also be used for fins that join at the fin ends by reversing the orientation of the plate in each adjacent layer. It is preferred for the multiple double sided plates to be similar to one another.

[0010] In example embodiments the fins are heat exchanger pins and hence they may extend from the body of the plates in a columnar fashion. The pins may have a circular cross-section. The pins may form an array with pins distributed across the body of the plate in a grid pattern, such as a square or diamond grid pattern. A diamond grid pattern in this sense has a line between opposite corners of the diamond aligned with the flow direction of the fluid flow path, whereas a square grid pattern has two sides of the square aligned with the flow direction. A diamond grid pattern has adjacent rows of pins that are staggered and this can aid heat transfer. One example uses a diamond grid pattern with right angled corners, which has staggered rows of pins and equal spacing between all adjacent pins.

[0011] The fins that extend toward each other from adjacent plates may be arranged in an array with a similar or identical pattern. As noted above the fin ends may be bonded to fins of the adjacent plate and thus there may be abutting fin ends at the join between adjacent plates. Alternatively the fin ends may be joined to the adjacent plate between the fins of the adjacent plate, and thus they may be bonded to the body of the adjacent plate. In the latter case the fins of adjacent plates may be interleaved in a repeating arrangement with fins of a first plate being either side of a fin of the second plate, and vice versa. The heat exchanger device may have a combination of these arrangements and hence may include some adjacent plates where the fin ends are joined and other adjacent plates where the fins are interleaved. It should be noted that the interleaved arrangement does not of course apply to fins at the outer edges of the plates, since there would be no adjacent fin on the outside of the outermost fins. All of the fins aside from the outermost fins may be interleaved with fins from the adjacent plate.

[0012] The fin ends may be shaped such that they can be bonded effectively to the adjacent plate. For example the ends may be substantially flat in order to be placed against and bonded to a flat surface at the fin ends or between the fins of the adjacent plate, or the fin ends may be curved in order to fit with a curved surface of the adjacent plates, for example a curved surface of a recess between the fins of the adjacent plate.

[0013] The heat exchanger fins may have any suitable size and shape, and the spacing between the fins and/or between adjacent plates may be set as required based on the particular intended use for the heat exchanger device. In example implementations, which may have advantages for use in aerospace, the spacing between adjacent plates may be in the range 1 to 30 mm, optionally in the range 2 to 10 mm, the fins may have a minimum width (which may be a diameter of a pin fin) in the range 0.25 to 10 mm, optionally in the range 0.5 to 2 mm and/or the spacing between centres of adjacent fins (i.e. the pitch of the fins) may be in the range 0.5 to 20 mm, optionally in the range 1 to 10 mm. The fins may extend from the body of the plate by 0.5 to 30 mm, optionally by 1 to 10 mm. The total thickness of the double sided plates may be 1.5 to 70 mm, optionally 2 to 30 mm. The dimensions and spacing of the fins may be the same for each plate in the heat exchanger device, or alternatively the dimensions and spacing may differ for different plates.

[0014] It will be understood that in the case where fin ends of adjacent plates are bonded together then the spacing between the plates will be the sum of the distances that the fins extend outward from the adjacent plates, i.e. twice the distance if the fins have a similar size, and the spacing between the fin centres of adjacent fins will be the same as the spacing between fins on each plate. Alternatively, in the case where the fins are interleaved and the fin ends are bonded to the adjacent plate in between the fins of that plate then the spacing between plates will be the same as the distance that the fins extend outward from the plates and the spacing between centres of adjacent fins will be the spacing between the interleaved fins, and hence half of the spacing between the centres of the fins on each plate if the fins on each plate have the same spacing and are evenly distributed. In the latter case the fins on the adjacent plates should extend outward from both of those plates by the same distance in order to permit both sets of fin ends to join to and be bonded to the plate at the opposite side.

[0015] In some examples the fins extend from the body of the plate by up to five times the minimum width or diameter of the fins, optionally between one and two times the width or diameter of the fins. The spacing between the fins may be less than three times the minimum width or diameter of the fins, optionally less than two times the minimum width or diameter of the fins. When the fins are interleaved then the spacing may be smaller than when the fins meet with the ends of fins from the opposite plate. It can be an advantage to have the fins close together in order to increase the heat transfer by maximising the ratio of the exposed surface area of the fins to the volume of the fluid. In this discussion the minimum width or diameter of the fins is referenced to take account of the fact that in many cases, for example where the fins are manufactured by chemical etching, the fins will not have a uniform width or diameter along the whole of their extent from the body of the plate to the fin ends. The fins may have the minimum width or diameter at the fin ends.

[0016] In the case where the fins are pins then the width measurements referenced above will be diameters of the pins. The spacing between the centres of the pins may refer to the smallest distance between a pin and nearby pins in the array of pins, which may for example be the length of a side of a grid pattern when the pins are in a grid pattern, i.e. the length of the side of the square in a square grid pattern or the length of a side of the diamond in a diamond grid pattern.

[0017] The double sided plates may advantageously be formed in a single piece, and hence may comprise a homogeneous body of material with no bonding between separate parts. This might be achieved by the use of machined, moulded, cast, forged or stamped plates, for example. Additive manufacturing techniques may also be used to make the plates. One implementation of single piece plates uses chemical etching to form the structure of the plates. Thus, the plates may be formed by etching away material on both sides of a blank plate with a suitable mask that is arranged to leave the required fins extending outward from the body of the etched plate. The use of a single piece with a homogeneous body of material provides advantages in relation to heat transfer and strength of the plates, which then further enhances the advantages of the heat exchanger device when multiple such plates are bonded together via the fin ends as in the first aspect. All of the plates may be manufactured with the same technique, for example all plates may be etched.

[0018] Producing fins such as pins by etching has the result that there is not a constant cross-section along the extent of the fins. The base of the fins will typically be somewhat wider than the ends of the fins due to the etching process. This can provide benefits from added strength, but it limits the minimum spacing between fins on each plate. It is therefore beneficial to combine the feature of double sided etched plates with the use of interleaved fins, which allows for the spacing between fins to be reduced whilst also retaining the benefits of manufacturing by etching. Thus, in one example some or all of the double sided plates are etched and some or all of adjacent pairs of the etched plates have interleaved fins, with the fin ends bonded to the body of the adjacent plate in between fins of the adjacent plate.

[0019] The heat exchanger device may be for use with any required combination of fluids, such as liquid-liquid, liquid-gas or gas-gas heat exchange. The heat exchanger may use air for heating or cooling of another fluid. In some examples the heat exchanger is for aerospace use and the invention thus extends to an aircraft including the heat exchanger device. In context of aerospace use the fluids could include two or more of: atmospheric air, cabin air, engine oil, generator oil, coolant, fuel and so on.

[0020] The material of the double sided plates may be selected bearing in mind the intended use of the device and limitations arising from the temperatures and fluids involved in the use of the device. In particular, in some cases the material may be selected to withstand high or low temperatures, or to be resistant to chemically reactive fluids such as fuel or coolant. In one example the double sided plates comprise aluminium and may be an aluminium alloy. Alternatively a stainless steel or copper based material may be used. It will be appreciated that metals such as aluminium can be readily etched, and that they provide a high conductance of heat. Non-metallic materials may also be used, such as ceramic or plastic materials.

[0021] The method used for bonding the fin ends to the adjacent plates may be selected based on the materials that are involved. Where metals such as aluminium alloys are used then brazing is a suitable joining technique.

[0022] The heat exchanger device is a multilayer structure with many plates, generally arranged in a repeating pattern in respect to the flow of fluids. There may for example be at least 40 plates, optionally at least 60 plates and in some cases 100 or more plates. The size and flow capacity of the heat exchanger device increases with the addition of more plates, which adds more flow paths, and thus more plates may be added as required to provide the necessary performance. The heat exchanger device may have a laminate structure, with the multiple plates coupled together by the bonding of the fin ends to adjacent plates and optionally also by a frame or supporting structure that clamps the plates together. The thickness of the heat exchanger device as a whole is set by the plate thickness, the number of plates, and whether the fins are interleaved or meet at the fin ends.

[0023] The heat exchanger device may be finstock provided as a part of a larger heat exchanger system, with this larger heat exchanger system comprising fluid inlet and outlet passages as well as optionally other features such as a frame for supporting the finstock and manifold structures for distribution of fluid to the flow paths. Alternatively the heat exchanger device may include fluid inlet and outlet passages and/or manifold structures coupled to or optionally integrated with the double sided plates. In either case the heat exchanger device may utilise the strength and stiffness of the layered double sided plates to provide strength and stiffness to the device as a whole. In either case the heat exchanger device may include end plates of differing form to the double sided plates, for example the end plates may have fins extending from only one side of the body of the plate and with the other side of the body of the plate forming an outside surface of the heat exchanger device and having no fins. Thus, the end plates may be single sided plates. In some examples the heat exchanger device may have to end plates and multiple double sided plates in between the end plates, optionally with only double sided plates in between the end plates.

[0024] The manifolds may include a least a primary fluid inlet manifold, primary fluid outlet manifold, a secondary fluid inlet manifold and a secondary fluid outlet manifold. Thus, the heat exchanger device may be used for heat exchange with at least two fluids. Further manifolds could be added to allow for multistream arrangements with more than two fluids.

[0025] As noted above, the heat exchanger device may be arranged for flow of two or more fluids in flow paths between the double sided layers. At the outer ends of the heat exchanger device the flow paths may optionally be between single sided end plates and a double sided plate adjacent to the end plate. Flow paths defined between generally planar plates will be in parallel planes, with heat transfer occurring generally perpendicular to the planes. The heat exchanger device may be arranged with multiple identical flow paths formed by repeating identical double sided plates in the stack. This might be used with alternating fluids in adjacent flow paths, such that a first fluid flows through the first, third and subsequent flow paths, and a second fluid flows through the second, fourth and subsequent flow paths. Alternatively there may be a need for a greater flow cross-section for one fluid, in which case that fluid may be flowed through two adjacent flow paths alternating with one flow path for another fluid, such as by having a first fluid in the first, fourth and seventh flow paths and subsequently in every third flow path and a second fluid in the second and third flow paths, then the fifth and sixth flow paths, and so on. Sometimes there are differing restrictions or requirements on the pressure drop and/or volume flow rate of one fluid compared to the other. Another possible way to provide for an increased volume flow rate and/or lower pressure drop for one fluid compared to another (without the use of different plate designs) is to vary the arrangement of the double sided plates, for example to alternate interleaved fins with fins that meet at the fin ends. A flow path through interleaved fins has a smaller cross-section and hence a smaller volume than a flow path through similar fins that meet at the fin ends, since the plates are further apart and the fins obstruct relatively less of the flow path.

[0026] Viewed from a second aspect, the invention provides a method of manufacturing a multilayer heat exchanger device comprising: forming multiple double sided plates, each plate having an array of heat exchanger fins extending outward from both sides of a body of the plate; and assembling the heat exchanger device by layering the double sided plates into a stack in order to provide multiple fluid flow paths separated by the plates; wherein the fins extend outward from both sides of the body of the plates into the fluid flow paths on either side of the plates; and wherein the assembly of the stack includes bonding outer ends of the fins on each side of the double sided plates to the fins or between the fins of the adjacent plates.

[0027] This method allows for effective manufacture of the heat exchanger device of the first aspect. The method may include forming the double sided plates and/or assembling the heat exchanger device with any of the features discussed above. The double sided plates may be similar or alternatively multiple designs of plates may be used. The multiple fluid flow paths formed between the double sided plates may be similar or they may differ in terms of the arrangement of the fins, the spacing of the plates and so on, again as discussed above. The method may include changing the orientation and/or offset of the plates when each of the plates is added to the stack, and/or selecting a different type of plate when each of the plates is added to the stack. Single sided end plates may be used as discussed above. The stack of plates may include any arrangement of and/or number of plates as discussed above, for example with parallel flow paths and so on. The step of assembling the heat exchanger device may include joining the layered double sided plates to manifolds for distribution of fluid during use of the heat exchanger device, such as the manifolds discussed above.

[0028] The method may include forming the double sided plates in a single piece, and hence they may comprise a homogeneous body of material with no bonding between separate parts. This might be achieved by the use of machined, moulded, forged or stamped plates, for example. One method for forming single piece plates includes using chemical etching to form the structure of the plates. Thus, the method may include etching away material on both sides of a blank plate using a suitable mask that is arranged to leave the required fins extending outward from the body of the etched plate. All of the plates may be manufactured with the same technique, for example all plates may be etched.

BRIEF DESCRIPTION OF THE FIGURES

[0029] Preferred embodiments of the invention are described below by way of example only and with reference to the accompanying drawings, in which.

[0030] FIG. **1** is a cross-section view showing significant dimensions for two single sided heat exchanger plates in a layered arrangement;

[0031] FIG. **2** is a diagram showing some of the same dimensions in a plan view of a part of a pin fin heat exchanger plate;

[0032] FIG. **3** illustrates the use of etching to manufacture pin fins on a single sided plate;

[0033] FIG. **4** is a top perspective view of a single sided plate produced in accordance with the etching technique of FIG. **3**;

[0034] FIG. **5** shows a layered heat exchanger device made up of multiple single sided plates of the type shown in FIG. **4**;

[0035] FIG. **6** shows a double sided plate with pins extending from two sides of the body of the plate where the pins are offset on each side;

[0036] FIG. **7** is a side view of a layered heat exchanger device made up of multiple double sided plates of the type shown in FIG. **6** with pins of adjacent layers interleaved;

[0037] FIG. **8** is a cross-section of the device shown in FIG. **7**;

[0038] FIG. **9** is a similar diagram to that of FIG. **1** showing the changes in the dimensions between two plates with the interleaved double sided plates of FIGS. **7** and **8**;

[0039] FIG. **10** shows another double sided plate with pins extending from two sides of the body of the plate where the pins of adjacent layers are aligned on each side;

[0040] FIG. **11** is a side view of a layered heat exchanger device made up of multiple double sided plates of the type shown in FIG. **10** with the pins of adjacent layers aligned with each other; and

[0041] FIG. **12** is a cross-section of the device shown in FIG. **11**.

DETAILED DESCRIPTION

[0042] Embodiments of a heat exchanger device with double sided plates can be considered as an improvement over similar devices manufactured with single sided plates. FIG. **1** illustrates a stacking arrangement of two such single sided plates **12**. Each of the single sided plates **12** has an array of fins **14** protruding from one side. The fins **14** extend from a body **16** of the plate and might for example be pin fins **14** arranged in a grid pattern. The fins **14** are spaced apart with a pitch P, which is the distance between the centres of the fins **14**. The spacing p between outer surfaces of the pins is the difference between the pitch P and the fin diameter D. In this case all of the pins **14** have the same diameter D. The plate **12** has a total height h, including the height of the fins **14** and the thickness t of the body **16**. In the example of a single sided plate **12** given here the stack of plates is joined together by brazing in order to bond the ends of the fins **14** to the underside of the next plate **12**. This process results in a change in the height of the fins **14**, with the post braze height of the fin **14** and plate **12** being shown as hb in FIG. **1**.

[0043] FIG. **2** illustrates some further parameters that might be measured in connection with arrays of pin fins **14** on the body **16** of the plate **12**. As shown in FIG. **2** adjacent rows of fins **14** can be staggered so that they are arranged in a diamond-like grid pattern with a pitch angle α between an axis of the plate **12** and a line intersecting the centres of the pin fins **14**. The transverse spacing St and the longitudinal spacing Sl may be the same, as shown here, or they may differ. If the transverse spacing St and the longitudinal spacing Sl are the same then the diamond grid is essentially a square grid turned to a pitch angle α of 45 degrees.

[0044] It is beneficial to be able to maximise the number of fin pins **14** per unit area of the plate **12**. There are various restrictions on the pitch P of the fin pins **14** as well as in some cases on the transverse spacing St and the longitudinal spacing Sl. These restrictions arise from the minimum sizes that can be formed using the selected manufacturing process. For example, in the case of etched pin fins **14** the pins **14** are not straight sided as shown in FIG. **1**, but instead have a curved conical profile as a consequence of the etching process, as explained below with reference to FIG. **3**. A similar restriction can arise with other manufacturing processes, for example the space required for moulds and/or tooling can restrict the minimum spacing for pin fins **14** formed on machined, moulded, forged or stamped plates.

[0045] In an etching process, as shown in FIG. **3**, a blank plate is fitted with masks **20** on both sides and then exposed to an etchant, for example by submersion in an acid **18**. The masks **20** prevent the etchant from etching away material beneath the masks **20** and thus if an array of circular masks is used then an array of circular pin fins **14** can be formed. However, since the etching process removes material evenly across the exposed surface then the etched plate **12** has pins **14** with a curved conical profile as shown in the Figure. For reference the dashed lines show the notional 'ideal' shape with straight sided pins **14**. Etching provides advantages in terms of the ease of manufacture of a relatively complicated shape and in the final strength and heat transfer characteristics, but the curved profile limits the minimum spacing of the fin pins **14** and thus limits the spacing p between outer surfaces of the pins **14** and the pitch P between the pins **14**.

[0046] FIGS. **4** and **5** show respectively a single sided plate **12** and a stack of single sided plates **12**. Each of the plates **12** has an array of pins **14** arranged in a diamond grid pattern with a pitch angle α of 45 degrees. When the single sided plates **12** are stacked, as shown in FIG. **5**, then a flow path is formed between each pair of adjacent plates, with the flow path passing through the gaps between the pins **14** and being forced to flow around the pins **14**. This hence provides a heat exchanger device where a first fluid can be flowed through one set of flow paths, for example the first, third and fifth flow paths and so on, and a second fluid can be flowed through the other set of flow paths, for example the second, fourth and six flow paths and so on. Heat will be transferred across the plates and the presence of the arrays of pin fins **14** increases the effectiveness of the heat transfer. However, the limitation on the spacing of the pin fins **14** is a disadvantage of this arrangement.

[0047] An example of a double sided plate **22** is shown in FIG. **6** in perspective view, and shown when utilised in a stack of plates in FIGS. **7** and **8**. The double sided plate **22** can advantageously be formed using the same basic method as the single sided plate **12** described above, but with the addition that a thicker starting plate is used and the blank plate is etched from both sides in order to form arrays of pin fins **14** extending from both surfaces of a body **16** of the plate **22**. The plate **22** may be an aluminium alloy, for example. These double sided plates **22** can then be stacked in layers as shown in FIG. **7** and FIG. **8**. It will be appreciated that although the Figures show five plates stacked together in practice they could be any number of plates and typically there would be very many more than five plates, for example 50 or more or even 100 or more plates.

[0048] The double sided plates **22** of FIG. **6** have pin fins **14** arranged in a diamond grid pattern on both sides, but with an offset for one side compared to the other. As a consequence of this, when the plates **22** are layered together, the pin fins **14** are interleaved with the fins **14** of one plate **22** extending between the fins **14** of the adjacent plate **22**. A result of this is that the effective pitch P and the spacing p between surfaces of the pins **14** can be considerably reduced, despite the curved profile and the limitations of the manufacturing process. This then provides for increases in the number of pins per unit area, which can give rise to increases in performance of the heat exchanger. The ends of the pin fins **14** are bonded to the adjacent plate **22** in between the pin fins **14** of the adjacent plate **22**. Thus, as well as increased numbers of pins per unit area this double sided arrangement can also increase the strength of the device since there may be twice as many points of contact and twice the area of bonds between layers. The layers may be joined by brazing the ends of the pin fins **14** to the recesses between the pin fins **14** of the adjacent plate **22**.

[0049] FIG. **9** is a similar diagram to FIG. **1** and shows the effect of the double sided interleaved fin arrangement. In this diagram a double sided plate **22** is placed on top of a single sided plate **12**. The single sided plate **12** may be the end plate of a stack of plates **12**, **22** that forms the heat exchanger device, with subsequent layers being made of double sided plates **22** in repeating arrangement similar to the layers of FIGS. **7** and **8**. There are pin fins **14** extending on both sides of the plate **22**, which means that the pin fins **14** can be interleaved as shown in the Figures and each of the pin fins **14** (aside from the outermost pin fins **14**) extends between pin fins **14** of the adjacent plate. In the diagram of FIG. **9** the pin fin **14** on the lower side of the double sided plate **22** extends between the pin fins **14** on the upper side of the single sided plate **12**. When further double sided plates **22** are stacked on top then there can be interleaved pins **14** in each layer. The pitch P is half that of FIG. **1**, assuming that other dimensions remain the same. The spacing p between the fins **14** is greatly reduced. The effect of this is shown very clearly in the cross-section of FIG. **8**, where the small size of the passages between pin fins **14** can be seen.

[0050] Another arrangement for a double sided plate **22** is shown in FIGS. **10** to **12**. In this case the pin fins **14** are arranged in a diamond grid pattern on each side and they are aligned with each other on both sides of the body **16** of the plate **22**. When these double sided plates **22** are layered together, as shown in FIGS. **11** and **12**, then the pins **14** can be aligned and the plates can be joined by bonding ends of the pin fins **14** of one plate **22** to the ends of the pin fins **14** of the adjacent plate **22**. The spacing between the two plates **22** is hence twice the height of the pin fins **14** and the pitch P of the pins **14** is similar to that of FIG. **1**, but with a much greater cross-section for the flow path between and around the pins **14**, as can be seen from FIG. **12**. This arrangement can be useful when the pressure drop through the heat exchanger device is a design limitation.

[0051] It will be understood that the an arrangement with offset pin fins **14** as shown in FIGS. **6**-**8** could also be used to provide an arrangement with interconnected pin ends as in FIGS. **11** and **12**, by flipping the plates **22** over between each layer. The relative location of the pin fins **14** could also be varied between layers by offsetting the plates **22** relative to the adjacent plates **22**. This can move the pin fins **14** between a configuration in which they align with the pin fins **14** of adjacent plates **22** and a configuration in which they can be placed in between the pin fins **14** of adjacent plates. Thus, a single geometry for a double sided plate **22** could be used to make a stacked heat exchanger device with either interleaved pins **14**, or interconnected pin ends **14**, or a combination of both arrangements in different layers of the device.

[0052] A heat exchanger device comprising a layered structure as shown in any of FIGS. **8** to **12** can be used as heat exchanger with the addition of appropriate parts (not shown) to direct the flow of fluid between the different layers. For example, in the case of a heat exchanger for exchange of heat between a primary and a secondary fluid there may be a primary fluid inlet manifold, primary fluid outlet manifold, a secondary fluid inlet manifold and a secondary fluid outlet manifold. Suitable enclosure bars or the like may be used to ensure that fluid only enters/exits the manifolds to or from specific layers. The manifolds may in turn be connected to a broader system, for example a cooling or heating system, which may have circuits for circulation of the fluids to and from the heat exchanger device and other parts.

[0053] Although the present disclosure has been described with reference to particular embodiments, the skilled reader will appreciate that modifications may be made that fall within the scope of the disclosure as defined by the appended claims. For example, the Figures showing the double sided plates **22** have layers of identical plates **22** each having similar arrangements of pin fins **14**, but it will be appreciated that more complex arrangements could be used, with differing configurations for the different plates **22** that are layered together and/or with varying arrangements of the pin fins **14** on the two sides of each plate **22**.

[0054] The term "about" is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.

[0055] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0056] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

1. A multilayer heat exchanger device comprising:

a stack of double sided plates arranged to provide multiple fluid flow paths separated by the plates;

wherein the double sided plates each have an array of heat exchanger fins extending outward from both sides of a body of the plate into the fluid flow paths on either side of the plate; and

wherein outer ends of the fins of the double sided plates are bonded on each side of the plates to the fins, or between the fins, of the adjacent plates.

2. A multilayer heat exchanger device as claimed in claim **1**, wherein the heat exchanger device is arranged for forced flow of fluid through the fluid flow paths.

3. A multilayer heat exchanger device as claimed in claim **1**, wherein the fins are heat exchanger pins that extend from the body of the plates in a columnar fashion.

4. A multilayer heat exchanger device as claimed in claim **3**, wherein the pins form an array with pins distributed across the body of the plate in a grid pattern.

5. A multilayer heat exchanger device as claimed in claim **1**, wherein the fin ends of some or all plates are bonded to fins of the adjacent plate such that there are abutting fin ends at the join between adjacent plates.

6. A multilayer heat exchanger device as claimed claim **1**, wherein the fin ends of some or all plates are joined to the adjacent plate between the fins of the adjacent plate and bonded to the body of the adjacent plate such that the fins of adjacent plates are interleaved with fins of a first plate being either side of a fin of the second plate and vice versa.

7. A multilayer heat exchanger device as claimed in claim **5**, wherein the heat exchanger device includes some pairs of adjacent plates where the fin ends are joined and other pairs of adjacent plates where the fins are interleaved.

8. A multilayer heat exchanger device as claimed in claim **1**, wherein the spacing between adjacent plates is in the range 2 to 10 mm, the fins have a minimum width in the range 0.5 to 2 mm, the spacing between centres of adjacent fins is in the range 1 to 10 mm and the fins extend from the body of the plate by 1 to 10 mm.

9. A multilayer heat exchanger device as claimed in claim **1**, wherein the spacing between the centres of the fins is less than three times the minimum width of the fins.

10. A multilayer heat exchanger device as claimed in claim **1**, wherein the double sided plates are formed in a single piece.

11. A multilayer heat exchanger device as claimed in claim **1**, wherein the plates are formed by etching away material on both sides of a blank plate with a suitable mask that is arranged to leave the fins extending outward from the body of the etched plate.

12. A multilayer heat exchanger device as claimed in claim **1**, wherein the double sided plates comprise aluminium.

13. A multilayer heat exchanger device as claimed in claim **1**, wherein the fin ends are bonded to the adjacent plate by brazing.

14. A multilayer heat exchanger device as claimed in claim **1**, wherein the heat exchanger device is a multilayer structure with at least 40 plates arranged in a repeating pattern in respect to the flow of fluids.

15. A multilayer heat exchanger device as claimed in claim **1**, wherein the heat exchanger device includes end plates with fins extending from only one side of the body of the plate and with the other side of the body of the end plates forming an outside surface of the heat exchanger device and having no fins.

16. A multilayer heat exchanger device as claimed in claim **1**, wherein the heat exchanger is for aerospace use.

17. An aircraft including a multilayer heat exchanger device as claimed in claim **1**.

18. A method of manufacturing a multilayer heat exchanger device comprising:

forming multiple double sided plates, each plate having an array of heat exchanger fins extending outward from both sides of a body of the plate; and

assembling the heat exchanger device by layering the double sided plates into a stack in order to provide multiple fluid flow paths separated by the plates;

wherein the fins extend outward from both sides of the body of the plates into the fluid flow paths on either side of the plates; and wherein the assembly of the stack includes bonding outer ends of the fins on each side of the double sided plates to the fins, or between the fins, of the adjacent plates.

19. A method as claimed in claim **18**, comprising forming the double sided plates.

20. A method as claimed in claim **18**, comprising etching away material on both sides of a blank plate using a suitable mask that is arranged to leave the required fins extending outward from the body of the etched plate.

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