



(11)

EP 3 301 391 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.04.2018 Bulletin 2018/14

(51) Int Cl.:
F28D 15/02 (2006.01) F28D 15/04 (2006.01)

(21) Application number: **16306250.8**

(22) Date of filing: **28.09.2016**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(72) Inventors:
• **STAFFORD, Jason**
DUBLIN, 15 (IE)
• **JEFFERS, Nicholas**
DUBLIN, 15 (IE)

(74) Representative: **Shamsaei Far, Hassan**
Alcatel-Lucent International
Patent Business
Site Nokia Paris Saclay
Route de Villejust
91620 Nozay (FR)

(71) Applicant: **ALCATEL LUCENT**
92100 Boulogne-Billancourt (FR)

(54) **A HEAT TRANSFER STRUCTURE**

(57) A heat transfer structure comprising a plurality of heat pipes, and a cooling chamber. Respective evaporator sections of each one of the heat pipes are configured to be thermally coupled to a respective heat source. Each heat pipe is configured to transfer heat from the respective evaporator section, to the cooling chamber, through its respective condenser section. A fluid is made to move into the cooling chamber through a fluid conduit

which is then moved out of the cooling chamber to thereby transfer heat from the cooling chamber to a surrounding medium. In some embodiments, the heat transfer structure has a fluid mover to force the fluid cooling chamber move in and out of the cooling chamber. In some embodiments, the fluid mover is located inside the cooling chamber.

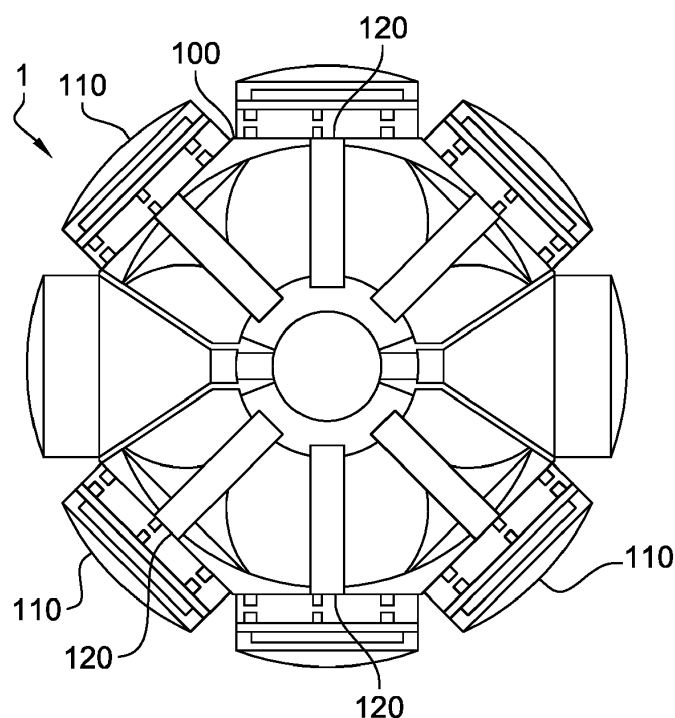


Fig. 1

Description

[0001] The present disclosure relates to a heat transfer structure. In particular the disclosure relates to a heat transfer structure that uses heat pipes, among other elements.

BACKGROUND ART

[0002] Electronic and optical systems contain components that generate heat during their operations. In modern electronic or optical systems, the heat sources (i.e. the electronic or optical components) are often densely packed in small or even miniature housings. Despite the small space available surrounding such components, these components still need to be maintained below certain temperature limits to ensure their reliability in operation.

SUMMARY

[0003] Some embodiments feature a heat transfer structure comprising:

- a plurality of heat pipes, each heat pipe from the plurality of heat pipes comprising a condenser section, an evaporator section, a working fluid and a wick structure;
- a cooling chamber confined within a housing and comprising a first fluid conduit; wherein:

respective evaporator sections of each one of the plurality of the heat pipes are configured to be thermally coupled to a respective heat source;

each one of the plurality of heat pipe is configured to transfer heat from the respective evaporator section, to the cooling chamber, through its respective condenser section;

the first fluid conduit is configured to allow passage of a fluid into the cooling chamber; and the heat transfer structure is configured to allow passage of the fluid out of the cooling chamber.

[0004] In some embodiments, the respective condenser section of each one of the plurality of heat pipe is, at least partially, located in or proximate to the cooling chamber.

[0005] In some embodiments, each on one of the plurality heat pipes extends from the cooling chamber such that the cooling chamber is common to respective condenser sections of the heat pipes.

[0006] In some embodiments, each one of the plurality of heat pipes extends radially from the cooling chamber thereby defining a spherical shape for the heat transfer structure.

[0007] In some embodiments, a second conduit is configured to allow the passage of the fluid out of the cooling

chamber to thereby transfer heat from the cooling chamber to a surrounding medium.

[0008] In some embodiments, one or more openings are provided on a housing of the cooling chamber are configured to allow the passage of the fluid out of the cooling chamber to thereby transfer heat from the cooling chamber to a surrounding medium.

[0009] In some embodiments, one or more heat sinks are provided thermally coupled to a respective heat pipe so as to enable heat transfer from the condenser section of the heat pipe to an ambient environment.

[0010] In some embodiments, the one or more heat sinks have a porous structure configured to allow for a passage of the air therethrough.

[0011] In some embodiments, the movement of the fluid into and out of the cooling chamber is by convection.

[0012] In some embodiments, the movement of the fluid into and out of the cooling chamber is provided by forcing the movement of the fluid using a fluid mover.

[0013] In some embodiments, the fluid mover is located outside the cooling chamber.

[0014] In some embodiments, the fluid mover is located inside the fluid chamber.

[0015] In some embodiments, the fluid mover comprises a plurality of blades, each blade having a first end and a second end wherein respective first ends of the plurality of blades are collectively joined to a first neck and respective second ends of the plurality of blades are collectively joined to a second neck, thereby collectively defining a multi-blade body.

[0016] In some embodiments, the multi-blade body is configured to rotate around a central axis to thereby cause the plurality of blades generate fluid flow in multiple directions.

[0017] In some embodiments, each blade has a structure such that an angle of attack at a central part of the blade is different from an angle of attack at an end of the blade.

[0018] In some embodiments, each blades has a structure configured to cause a flow of the fluid in the vicinity of the ends of the blade to be oriented in directions that are parallel or at small angles with respect to the central axis of the multi-blade body, and a flow of fluid in the vicinity of the central part of the blades to be oriented in directions that are perpendicular with respect to the central axis or at small angle with respect to said perpendicular direction.

[0019] In some embodiments, the air mover comprises a motor actionable using magnetic forces to produce rotation.

[0020] In some embodiments, the motor comprises at least two magnetic elements having respective shapes in conformity with each other such that one can be placed inside the other, and wherein a first one of the magnetic elements is made of permanent magnet and a second one of the magnetic elements is connected to an electronic circuitry configured to induce a magnetic field around said second magnetic element such that mag-

netic fields between the two magnetic elements oppose each other to thereby cause one magnetic element levitate with respect to the other.

[0021] In some embodiments, the electronic circuitry is configured to vary the magnetic field in the second magnetic element to cause the first magnetic element to levitate and rotate with respect to the second magnetic element.

[0022] In some embodiments, the fluid mover has a shape in conformity with the shape of the cooling chamber.

[0023] In some embodiments, the fluid is air.

[0024] Some embodiments feature a fluid mover comprising a plurality of blades, each blade having a first end and a second end wherein respective first ends of the plurality of blades are collectively joined to a first neck and respective second ends of the plurality of blades are collectively joined to a second neck, thereby collectively defining a multi-blade body.

[0025] In some embodiments, the multi-blade body is configured to rotate around a central axis to thereby cause the plurality of blades generate fluid flow in multiple directions.

[0026] In some embodiments, each blade has a structure such that an angle of attack at a central part of the blade is different from an angle of attack at an end of the blade.

[0027] In some embodiments, each blades has a structure configured to cause a flow of the fluid in the vicinity of the ends of the blade to be oriented in directions that are parallel or at small angels with respect to the central axis of the multi-blade body, and a flow of fluid in the vicinity of the central part of the blades to be oriented in directions that are perpendicular with respect to the central axis or at small angle with respect to said perpendicular direction.

[0028] In some embodiments, the air mover comprises a motor actionable using magnetic forces to produce rotation.

[0029] In some embodiments, the motor comprises at least two magnetic elements having respective shapes in conformity with each other such that one can be placed inside the other, and wherein a first one of the magnetic elements is made of permanent magnet and a second one of the magnetic elements is connected to an electronic circuitry configured to induce a magnetic field around said second magnetic element such that magnetic fields between the two magnetic elements oppose each other to thereby cause one magnetic element levitate with respect to the other.

[0030] In some embodiments, the electronic circuitry is configured to vary the magnetic field in the second magnetic element to cause the first magnetic element to levitate and rotate with respect to the second magnetic element.

[0031] In some embodiments, the fluid mover has a shape in conformity with the shape of the cooling chamber.

[0032] These and further features and advantages of the present invention are described in more detail, for the purpose of illustration and not limitation, in the following description as well as in the claims with the aid of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033]

Figure 1 is a schematic representation of an example of a heat transfer structure used in a device according to some embodiments.

Figure 2 is a partial schematic representation of the heat transfer structure of figure 1.

Figure 3 is a partial schematic representation of the heat transfer structure of figure 1 and including an air mover according to some embodiments.

Figure 4 shows a schematic example of an air mover for use inside the cooling chamber of the heat transfer structure for figure 3.

Figures 5A and 5B show schematic partial elements of an example of a motor useable in the air mover of figure 4.

Figure 6 is a schematic partial representation of the heat transfer structure according to some embodiments.

DETAILED DESCRIPTION OF ILUSTRATIVE EMBODIMENTS

[0034] As mentioned above modern electronic or optical components are often densely packed inside small or even miniature housings. Therefore, an efficient transfer of the heat generated by these components in the smallest volume possible is becoming a key requirement. One aspect of such efficient heat transfer is that the thermal management system installed in the equipment is less obtrusive on the overall architecture. Current heat pipes and heat exchangers are being designed for this purpose; however they are typically constructed from an assembly of individual parts designed separately from each other. One drawback associated with this type of construction is that it is non-optimal in thermal performance. Another drawback associated with these structures is that they typically occupy relatively large volumes due to their relatively large size.

[0035] Currently, heat pipes, heat sinks and heat exchangers are typically constructed from common metal processing techniques. Heat pipes are typically manufactured using copper pipes that undergo processes which may include powder filling, heat treatments, liquid filling, evacuation and degassing. Heat pipes typically have a single evaporator where a working fluid within the heat pipe evaporates from its liquid phase upon receiving heat from a heat source (e.g. a hot component) and a single condenser transferring the heat from the hot vapor to a medium where heat is dissipated, e.g. a heat sink,

to thereby condense the vapor back to liquid. Heat sinks and multi fluid heat exchangers also typically utilize standard manufacturing processes including casting, machining, extrusion, folded and skived fins. As a result, some known heat pipes and heat exchangers are constrained to simply shaped designs that are two-dimensional extrusions of objects, for example in extended planar rectangular or circular shapes.

[0036] Constraining the design of the heat exchanger to such non-arbitrary shapes ultimately constrains the overall product (or equipment) design. Given that the volume of the cooling solution can, in many applications, be above 50% of the total product volume, this constraint may consequently also impact the final product shape and aesthetics. Hence, many of the conventional electronic or optical systems (e.g. metrocells, remote radio heads, servers, cabinets, etc.) are configured such that they can accommodate the above-mentioned extended planar heat bodies, for example in 'box'-like shapes.

[0037] This type of design philosophy negatively impacts the thermal performance capabilities of modern complex, high density systems. In order to overcome the above drawbacks, new approaches in the design of thermal solutions are desired which is capable of conforming to arbitrary shapes and structures of the equipment in which they are installed.

[0038] Furthermore, it is desirable to provide a heat transfer structure that is capable of being designed and manufactured as one complete unit from the start (i.e. that is not an assembly of individually fabricated heat pipe and heat sink parts), can be fit in smaller volumes, can transfer heat from multiple heat sources and can improve heat transfer efficiency. Making a heat transfer structure as one complete unit is advantageous because it may enable higher levels of total heat dissipation in a given volume, as compared to a conventional heat transfer assembling with individually designed and manufactured heat pipes and heat sinks that are subsequently assembled together. In the latter case, when one assembles the parts together it is typically unlikely that the final heat transfer structure will provide an optimal performance for the volume it occupies.

[0039] Figure 1 shows a schematic representation of an example of a heat transfer structure 100 used in a device 1. Device 1 may be an electronic or an optical device or any combination thereof. Some non-limiting examples of device 1 may be an antenna array for wireless communication or a device for emitting light in multiple directions. The device 1, including the heat transfer structure, in this example is shown to have a spherical shape, however this is only one specific example of the shape that device 1 may have and other shapes and designs for the device 1 may also be envisaged within the scope of the present disclosure.

[0040] As shown in figure 1, device 1 has a plurality of heat sources 110 (e.g. electronic components or light emitting elements) installed in a spherical arrangement to ensure transmission (e.g. of radio signals or light

beams) in multiple directions.

[0041] Each heat source 110 may be thermally coupled to a respective heat pipe 120.

[0042] The terms "thermally coupled" and "thermal coupling" or associated terms, as used herein is to be understood in a broad sense, encompassing situations in which the heat source and the heat pipe are in direct physical contact to transfer heat; or situations in which such contact is provided indirectly, for example by having an intermediate layer of material between the heat source and the heat pipe capable of ensuring improved heat transfer. Such material may be for example a sheet of metal or a layer of grease.

[0043] As can be seen on figure 1, and will be further described in figure 2, the heat pipes extend (radially in the example of figure 1) from a central region which is common to respective ends of the heat pipes 120.

[0044] Figure 2 shows a partial representation of the heat transfer structure 100 of figure 1 in which for simplicity only one heat source-heat pipe pair is shown. The rest of the plurality of heat source-heat pipe pairs, not fully shown, may have similar structures and functionalities. Heat source 110 may include a plurality of components generally shown by reference numeral 111. Such components may be electronic or optical. Components 111 may be located on a suitable support structure 112 such as a substrate made of a material with good thermal conductivity.

[0045] Heat source 100 is thermally coupled to the heat pipe 120. In the example shown in figure 2, the thermal coupling is provided by contact between the heat pipe 120 and the support structure 112 of the heat source 110.

[0046] Each one of the heat pipes 120 may comprise a condenser section 121, an evaporator section 122 and an intermediate adiabatic section 123. A working fluid 124 capable of changing phase from liquid to vapor and vice-versa, in response to exchange of heat with the surroundings, is provided inside the heat pipe, as known in the related art. The working fluid 124 may be, for example, water. However other known working fluids may also be used depending on each specific application. The choice of working fluid can for example be based on the operating temperature range of each specific application because different working fluid may change phase at different temperatures, as is known in the related art.

[0047] Heat pipe 120, may further comprise a wick structure 125 for transferring liquid from the condenser section 121 to the evaporator section 122 by capillary effect.

[0048] The condenser section 121 is, at least partially, located in or proximate to a cooling chamber 130 containing a convective medium, such as, for example, air.

[0049] The cooling chamber 130 is confined within a housing 131 which also receives respective condenser sections 121 of the rest of the heat pipes 120 of the heat transfer structure 100. The rest of the heat pipes 120, being thermally coupled to respective heat sources at their respective evaporator ends, are configured to trans-

fer heat from their respective evaporator sections, to the convective medium within the cooling chamber 130 in a similar fashion as described above.

[0050] The cooling chamber 130 is further provided with fluid conduits 140. The fluid conduits 140 are configured to allow for the passage of a cooling fluid into and out of the cooling chamber 130. For example ambient air may be made to flow through one conduit 140 into the cooling chamber 130 and to flow through another fluid conduit 140 out from the cooling chamber 130. In figure 2, only two fluid conduits have been shown. This however is only exemplary and the heat transfer structure of the present disclosure can include any suitable number of conduits as may be required for a specific application.

[0051] In the following an example of an embodiment is provided in which use is made of air as a fluid to move inside the cooling chamber to cool the condenser sections. The disclosure however is not so limited and other fluids may also be used according to specific requirements and designs within the scope of the present disclosure.

[0052] The heat transfer structure 100 of the present disclosure may be used to transfer heat from multiple heat sources 110 as described below. Heat generated by components 111 during their operation is transferred to the evaporator section 122 of the heat pipe 120. Such transfer of heat may, for example, be made using a support structure 112 such as a substrate made of a material with good thermal conductivity. The evaporator section 122 is configured to receive liquid from the wick structure 125 which in turn absorbs the liquid 124 from the condenser section 121 and transports the liquid to the evaporator section 122 by capillary action.

[0053] Upon reaching the evaporator section 122, which is heated due to the presence of thermal coupling with the heat source 110, the liquid evaporates as schematically shown by reference numeral 126. The vapor 126 thus produced moves to the condenser section 121 (due to temperature difference and/or pressure difference between the two sections) where it is condensed and changes phase from vapor 126 into liquid 124.

[0054] The condensation of the vapor into liquid is achieved due to the cooling effect of air moving within the cooling chamber 130 in which the condenser section is, at least partially, inserted. The movement of the air within the cooling chamber may be due to convection and has the effect of removing the heat from the condenser section which is heated from the vapor that arrives at the condenser section 121.

[0055] As the condenser sections of all the heat pipes 120 are, as shown in figure 2, at least partially inserted inside the cooling chamber 130, the respective condenser sections of each of the heat pipes undergo similar cooling processes. Therefore the plurality of the heat pipes are simultaneously cooled. Furthermore as the air, in the cooling chamber 130 absorbs heat from the heat pipes 120, its temperature increases. The increase in temperature of the air inside the cooling chamber 130 gives rise

to a difference in temperature between the air inside the housing 131 and the air in the surroundings of the cooling chamber thereby causing the heated air to move, due to convection, out of the cooling chamber 130, through a conduit 140. This, in turn, causes the outside air, which is cooler, to move inside the cooling chamber 130, through another conduit 140. The movement of the air in and out of the cooling chamber is represented in figure 2 by arrows F.

[0056] As the cooling chamber 130 is common to the plurality of the heat pipes 120, various heat sources 110 (electronic or optical components) can be efficiently cooled with the use of only one heat transfer structure and without the need for using bulky heat sinks. Furthermore, as the shape of the cooling chamber may be designed in conformity with the space available inside the equipment, great flexibility is provided in overall layout of the equipment and its internal components. Likewise, the shape and/or the manner of distribution of the heat pipes with respect to the cooling chamber may be designed with great flexibility and in view of the overall design requirements of the equipment.

[0057] In case a mere convection of air is not sufficient for providing an efficient cooling effect, e.g. in cases where the components' temperatures increase faster than the ability of the heat transfer structure to maintain them at a desired level of temperature, use may be made of forced movement of the air by using a device for forcing air into and out of the cooling chamber 130.

[0058] In some embodiments an air mover, e.g. a fan, may be provided external to the heat transfer structure. By using an air mover, air may be forced to enter into a first conduit 140, propagate into the cooling chamber 130 and finally forced out of the cooling chamber from a second conduit 140 as shown in figure 2 by arrows F (the air mover is not shown). The air mover may be a rotary fan or a piezoelectric fan or any other known fan suitable for the intended use.

[0059] In some embodiments, the air mover may be installed inside the cooling chamber 130. Figure 3 illustrates one way of implementing this configuration. In figure 3, like elements have been given like reference numerals as those of figure 2.

[0060] The heat transfer structure 100 of figure 3 differs from that of figure 2 in that the embodiment of figure 3 comprises an air mover 200 located inside the cooling chamber 130.

[0061] Preferably, the air mover 200 may be designed to have a shape in conformity with the shape of the cooling chamber. This will allow efficient usage of the space available inside the cooling chamber to provide improved air flow. In figure 3, the air mover has a spherical shape which, as will be described with reference to figure 4, may help generate a relatively even air movement in multiple directions. Figure 4 shows an example of an air mover 200, in this case a rotary fan, for use inside the cooling chamber of the heat transfer structure 100, according to some embodiments.

[0062] The fan 200 of figure 4 comprises a plurality of blades 210. Each blade 210 has a first end 211 and a second end 212. The first ends of the plurality of blades are collectively joined to a first neck 220 and the second ends 212 of the plurality of blades are collectively joined to a second neck 230. The blades 210 are positioned relative to each other so as to define a multi-blade body 214 having a spherical shape, such that each individual blade is generally oriented along a respective line of longitude of the sphere. The fan 200 may therefore be made to rotate around a central axis A-A' to cause the plurality of blades generate air flow in multiple directions covering a span of 360 degrees.

[0063] In some embodiments, the blades may be designed such that the angle of attack in each blade 210 changes to ensure an even airflow distribution. For example a blade may be made to have a larger angle of attack at the ends 211, 212 and a smaller angle of attack at the central part 213 thereof. This change in the angle of attack may be progressive, i.e. at a constant rate, or non-progressive, for example in the form of a stepwise change. In the absence of such change in the angle of attack of the blades, the movement of the air in the regions closer to the ends 211, 212 would be weaker than the movement of the air in the regions closer to the central part 213. By providing the above-described change in the angle of attack, an even distribution of airflow may be ensured.

[0064] The blades may also be designed such that the angle of attack changes in such a way that airflow in the vicinity of the ends 211 and 212 of the blades can be oriented in directions that are parallel or at small angles with respect to the central axis A-A' while airflow in the vicinity of the central part of the blades is perpendicular thereto. This arrangement is also advantageous as it allows for moving the air not only in a direction perpendicular to the central axis A-A' but at any desired angle as one moves from the central part 213 of the blade to the ends 211, 212 thereof, thus providing air distribution in practically all possible angles.

[0065] Fan 200 further comprises a motor 240 to cause the multi-blades body 240 to rotate so as to generate airflow.

[0066] In some embodiments, the motor 240 may be designed to operate using magnetic forces to produce rotation without using bearings and/or brushes that are used in some known motors. Figures 5A and 5B show partial elements of an example of a motor of such type which may be used in the fan of figure 4.

[0067] Figure 5A shows two magnetic elements 241, 242, having respective shapes in conformity with each other such that one can be placed inside the other. The two magnetic elements 241, 242 form part of the motor 240. In the example of figure 5A, the magnetic elements have truncated-cone shapes. However this is only exemplary and other geometrical shapes may be used within the scope of the present disclosure.

[0068] A first one of the two magnetic elements, for

example the outer element 241, may be made of permanent magnet and the second one, e.g. the inner magnetic element 242, may be connected to suitable electronic circuitry configured to induce a magnetic field around said second magnetic element 242. The magnetic forces (or magnetic fields) between the two magnetic elements 241, 242 may be configured to oppose each other. The opposing magnetic forces may be used for levitating one magnetic element with respect to the other. In this manner, the two magnetic elements are separated from each other with only air being present between them.

[0069] By varying the magnetic field in the second magnetic element 242, an interaction between the opposing forces of the two magnetic elements 241 and 242 may be produced which may cause the first magnetic element 241 to rotate, as it is levitated, with respect to the second magnetic element 242.

[0070] The motor 240 comprising the pair of the first magnetic element 241 and the second magnetic element 242 may be installed inside a cavity 243 provided at the neck 220 of the fan 200. The two magnetic elements 241 and 242 not only, in combination, facilitate the rotation functionality of the motor 240, but they are also used to constrain the structure of the multi-blade body 214. In this regard a second pair of magnetic elements may be provided at the opposite neck 230 (figure 4) of the multi-blade body 214 to provide the same effect of constraining the latter at the opposite neck 230.

[0071] As a result of the interaction of opposing magnetic forces between the first and the second magnetic elements 241, 242 and the levitation of one with respect to the other, friction between the moving parts of the fan 200 is avoided.

[0072] The absence of mechanical bearings in the fan 200 eliminates the generation of friction forces, this significantly increasing the reliability of the fan which is indeed a very important issue in many wireless or any forced cooled products using fans.

[0073] It is to be noted that although the air mover 200 of the embodiments of figures 4, 5A and 5B, has been described as an element to be used inside the heat transfer structure 100 of embodiments of figures 1, 2 and 3, those of ordinary skill in the related art would readily understand that the air mover 200 of the present disclosure does not necessarily have to be used in combination with the heat transfer structure 100, instead the air mover 200 is capable of being used independently of the heat transfer structure 100 in order to generate airflow in other applications.

[0074] In some embodiments the heat transfer structure 100 may be configured such that airflow may be pulled from the ambient environment into the cooling chamber 130 from both conduits 140 and expelled from other air outlets. Figure 6 represents a schematic view of such embodiments.

[0075] In figure 6 like elements have been provided with like reference numeral as those of figure 3. However the heat transfer structure of figure 6 further comprises

a plurality of openings 150 provided on the housing 131 to allow passage of air from inside the cooling chamber 130 to the ambient environment.

[0076] Fan 200 may be designed (e.g. by specific shaping of the angle of attack of the blades), so as to produce a lower rate of airflow in the vicinity of the ends of the blades 210, e.g. closer to the conduits 140 on both sides of the fan 200 in figure 6, and to produce higher rates of air flow at parts other than the end of the blades 210. In this manner, fan 200 may be operable to expel the air out of the cooling chamber 130 through openings 150 as shown by arrows E in figure 6. As the air is forced to move out of the cooling chamber 130, ambient air from outside the cooling chamber may be pulled inside the cooling chamber 130, due to the creation of a pressure difference between the inside and the outside of the cooling chamber 130, as shown by arrows F'.

[0077] In some embodiments, additional cooling mechanism may be provided to transfer heat from the condenser section 121 of the heat pipes 120 to the ambient environment by using heat sinks. Figure 6 illustrates an example of such embodiments where a plurality of heat sinks 160 are, for simplicity, only shown connected to three respective heat pipes 120 located at the lower part of the heat transfer structure 100. However, any suitable number of heat sinks on all or some of the heat pipes may be used. Each heat sink is thermally coupled to the respective heat pipe so as to enable heat transfer from the condenser section to the heat pipe to the ambient environment.

[0078] Preferably, some or all of the heat sinks 160 have a porous structure which is schematically shown in figure 6 by the use of broken lines to illustrate each heat sink 160. The porous structure allows for a more efficient passage of the air as it is forced out of the cooling chamber 130 while the heat sinks themselves also contribute to the cooling of the condenser section 121 of each respective heat pipe 120.

[0079] It is to be noted that although the use of heat sinks 160 has been illustrated with reference to the embodiment of figure 6 (which includes a fluid mover 200 and openings 150), the disclosure is not so limited and such heat sinks 160 may likewise be used in other embodiments where the fluid mover 200 and/or the openings 150 are not employed, such as for example the embodiments of figures 2 or 3. In such cases one or more heat sinks 160, being thermally coupled to a respective heat pipe 120 may be configured to transfer heat from the condenser section 121 of the heat pipe 120 to which they are connected to the ambient environment.

[0080] As can be appreciated, the various embodiments of the present disclosure provide a heat transfer structure with many important advantages, including the flexibility in shape thus enabling designs that can move away from today's conventional 'box'-shaped arrangements and morph the thermal management solution to the requirements of modern technologies.

[0081] The heat transfer structure as proposed herein

is also capable of being pluggable to a variety of modules, including but not limited to, radio antenna or lighting, for example in buildings.

[0082] With the advancements in additive manufacturing, that the heat transfer structure - including heat pipes, heat sink fins (if present), and mechanical structures - can be manufactured using additive manufacturing techniques. Modules for practical use such as lighting and wireless devices may then be 'plugged into' the heat transfer structure.

[0083] The various embodiments of the present invention may be combined as long as such combination is compatible and/or complimentary.

[0084] Further it is to be noted that the list of structures corresponding to the claimed means is not exhaustive and that one skilled in the art understands that equivalent structures can be substituted for the recited structure without departing from the scope of the invention.

Claims

1. A heat transfer structure comprising:

- a plurality of heat pipes, each heat pipe from the plurality of heat pipes comprising a condenser section, an evaporator section, a working fluid and a wick structure;
- a cooling chamber confined within a housing and comprising a first fluid conduit; wherein:

respective evaporator sections of each one of the plurality of the heat pipes are configured to be thermally coupled to a respective heat source;

each one of the plurality of heat pipe is configured to transfer heat from the respective evaporator section, to the cooling chamber, through its respective condenser section; the first fluid conduit is configured to allow passage of a fluid into the cooling chamber; and

the heat transfer structure is configured to allow passage of the fluid out of the cooling chamber.

2. The heat transfer structure of claim 1, wherein the respective condenser section of each one of the plurality of heat pipe is, at least partially, located in or proximate to the cooling chamber.

3. The heat transfer structure of claim 1 or claim 2, wherein each one of the plurality heat pipes extends from the cooling chamber such that the cooling chamber is common to respective condenser sections of the heat pipes.

4. The heat transfer structure of claim 3, wherein each

one of the plurality of heat pipes extends radially from the cooling chamber thereby defining a spherical shape for the heat transfer structure.

5. The heat transfer structure of any one of the preceding claims, wherein a second conduit is configured to allow the passage of the fluid out of the cooling chamber to thereby transfer heat from the cooling chamber to a surrounding medium.
6. The heat transfer structure of any one of the preceding claims, wherein one or more openings are provided on a housing of the cooling chamber are configured to allow the passage of the fluid out of the cooling chamber to thereby transfer heat from the cooling chamber to a surrounding medium.
7. The heat transfer structure of any one of the preceding claims, wherein one or more heat sinks are provided thermally coupled to a respective heat pipe so as to enable heat transfer from the condenser section of the heat pipe to an ambient environment.
8. The heat transfer structure of claim 7, wherein the one or more heat sinks have a porous structure configured to allow for a passage of the air therethrough.
9. The heat transfer structure of any one of the preceding claims, wherein the movement of the fluid into and out of the cooling chamber is by convection.
10. The heat transfer structure of any one of the claims 1 to 8, wherein the movement of the fluid into and out of the cooling chamber is provided by forcing the movement of the fluid using a fluid mover.
11. The heat transfer structure of claim 10, wherein the fluid mover is located outside the cooling chamber.
12. The heat transfer structure of claim 10, wherein the fluid mover is located inside the fluid chamber.
13. The heat transfer structure of claim 12, wherein the fluid mover comprises a plurality of blades, each blade having a first end and a second end wherein respective first ends of the plurality of blades are collectively joined to a first neck and respective second ends of the plurality of blades are collectively joined to a second neck, thereby collectively defining a multi-blade body.
14. The heat transfer structure of claim 15, wherein the multi-blade body is configured to rotate around a central axis to thereby cause the plurality of blades generate fluid flow in multiple directions.
15. The heat transfer structure of claims 13 or claim 14, wherein each blade has a structure such that an an-

gle of attack at a central part of the blade is different from an angle of attack at an end of the blade.

16. The heat transfer structure of claim 15, wherein each blades has a structure configured to cause a flow of the fluid in the vicinity of the ends of the blade to be oriented in directions that are parallel or at small angles with respect to the central axis of the multi-blade body, and a flow of fluid in the vicinity of the central part of the blades to be oriented in directions that are perpendicular with respect to the central axis or at small angle with respect to said perpendicular direction.
17. The heat transfer of any one of claims 12 to 16, wherein the air mover comprises a motor actionable using magnetic forces to produce rotation.
18. The heat transfer structure of claim 17, wherein the motor comprises at least two magnetic elements having respective shapes in conformity with each other such that one can be placed inside the other, and wherein a first one of the magnetic elements is made of permanent magnet and a second one of the magnetic elements is connected to an electronic circuitry configured to induce a magnetic field around said second magnetic element such that magnetic fields between the two magnetic elements oppose each other to thereby cause one magnetic element levitate with respect to the other.
19. The heat transfer structure of claim 18, wherein the electronic circuitry is configured to vary the magnetic field in the second magnetic element to cause the first magnetic element to levitate and rotate with respect to the second magnetic element.
20. The heat transfer structure of any one of the preceding claims 12 to 19, wherein the fluid mover has a shape in conformity with the shape of the cooling chamber.
21. The heat transfer structure of any one of the preceding claims, wherein the fluid is air.

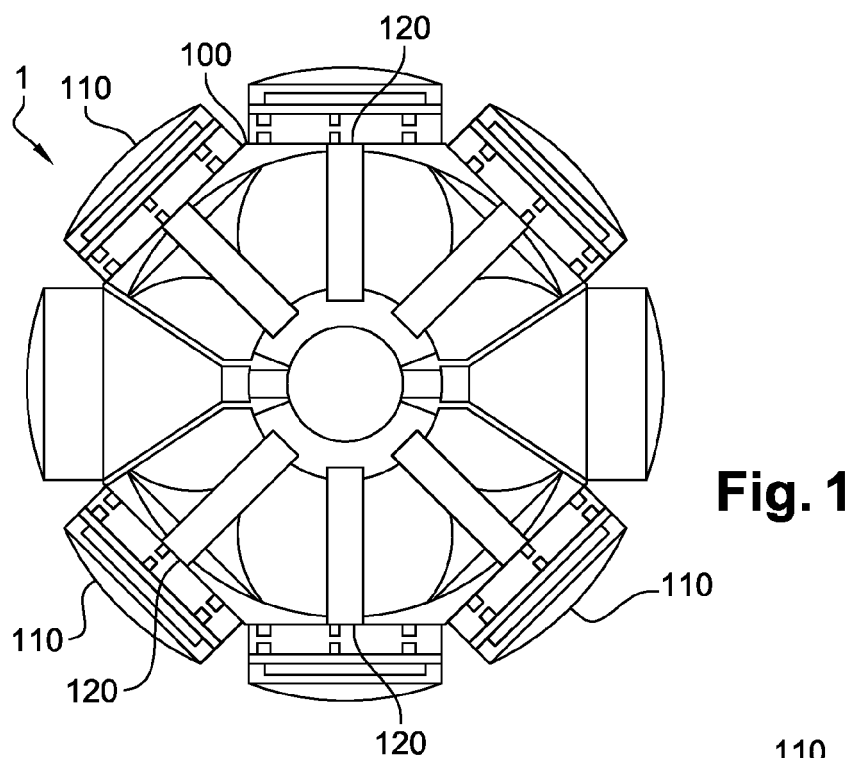


Fig. 1

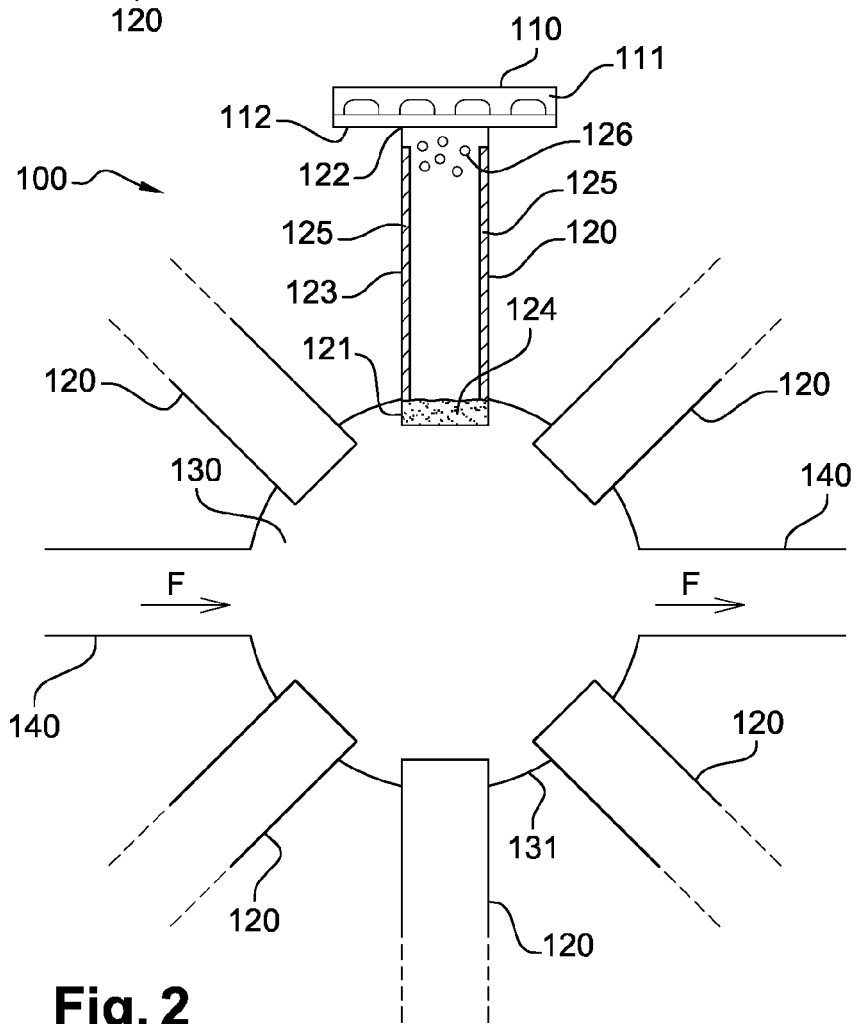


Fig. 2

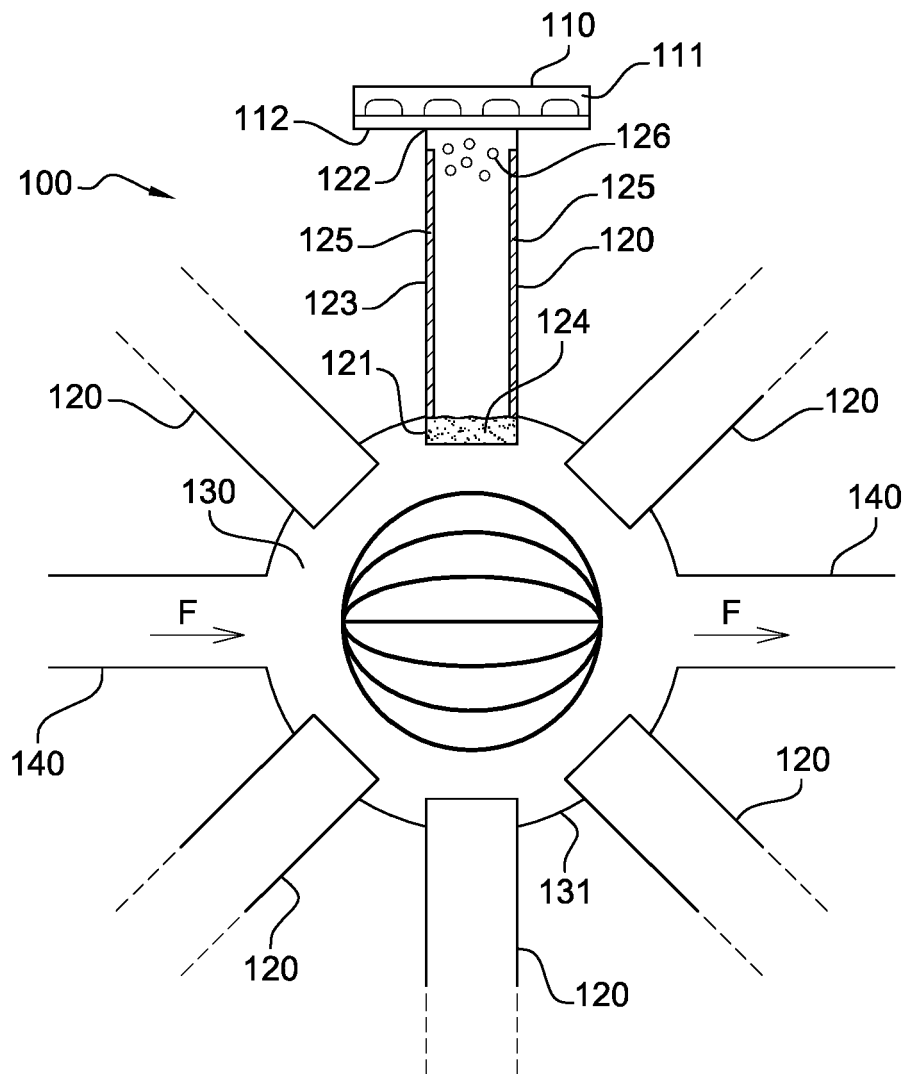


Fig. 3

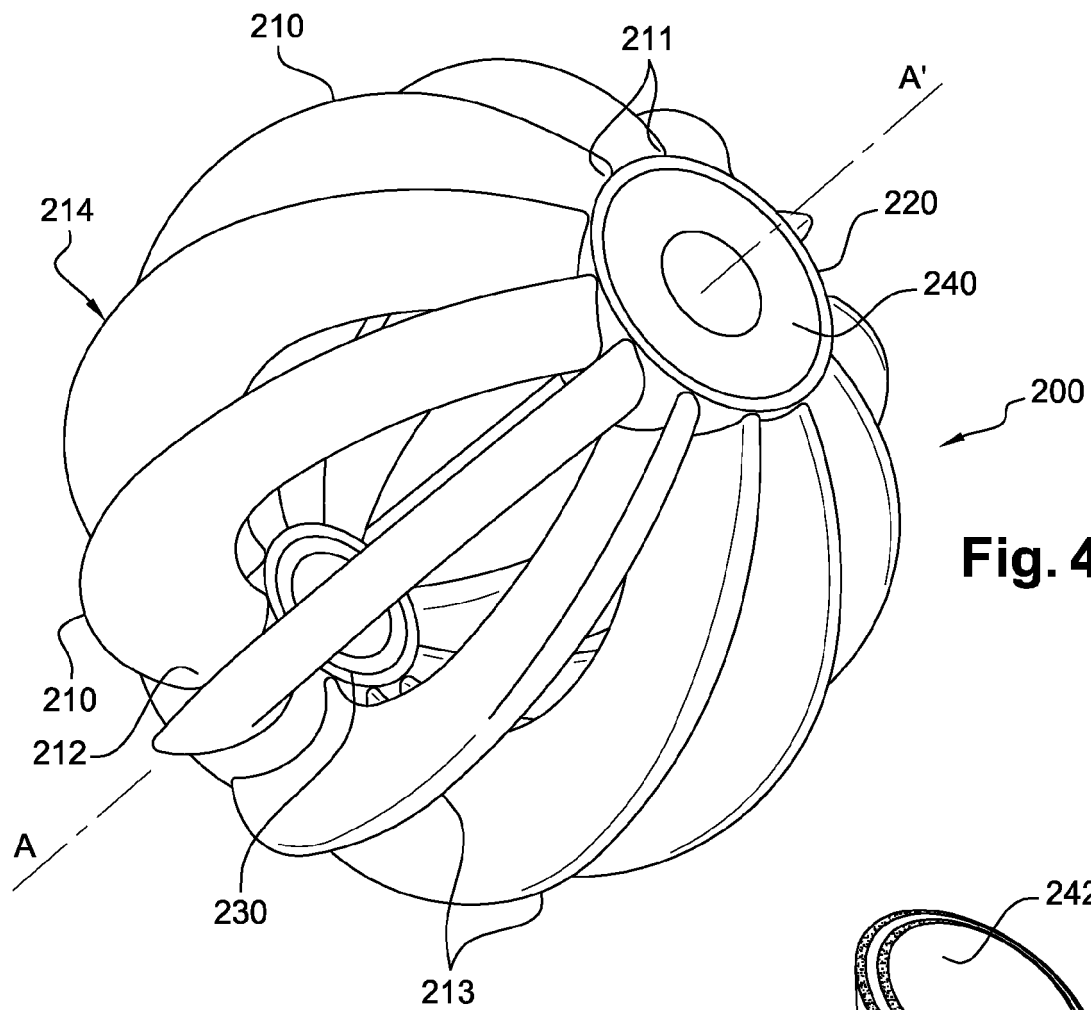


Fig. 4

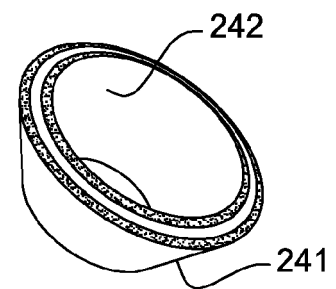


Fig. 5A

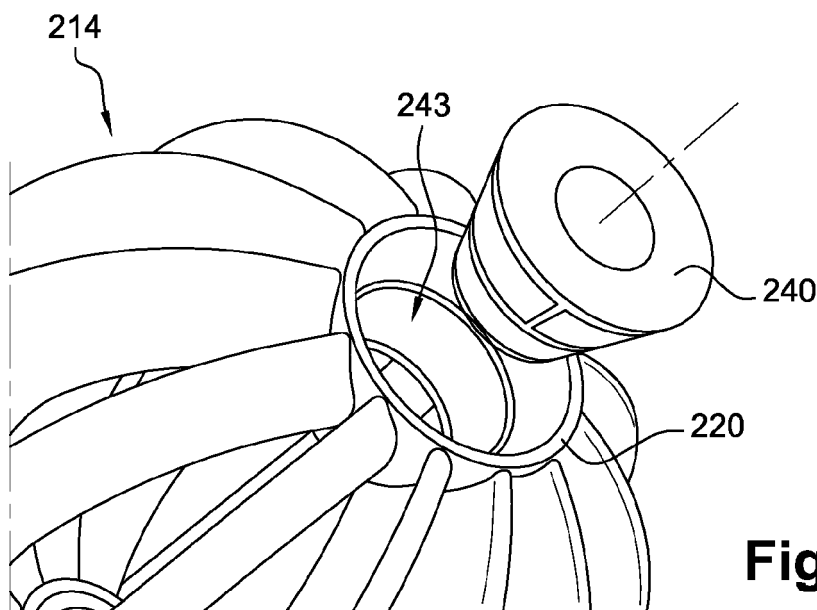


Fig. 5B

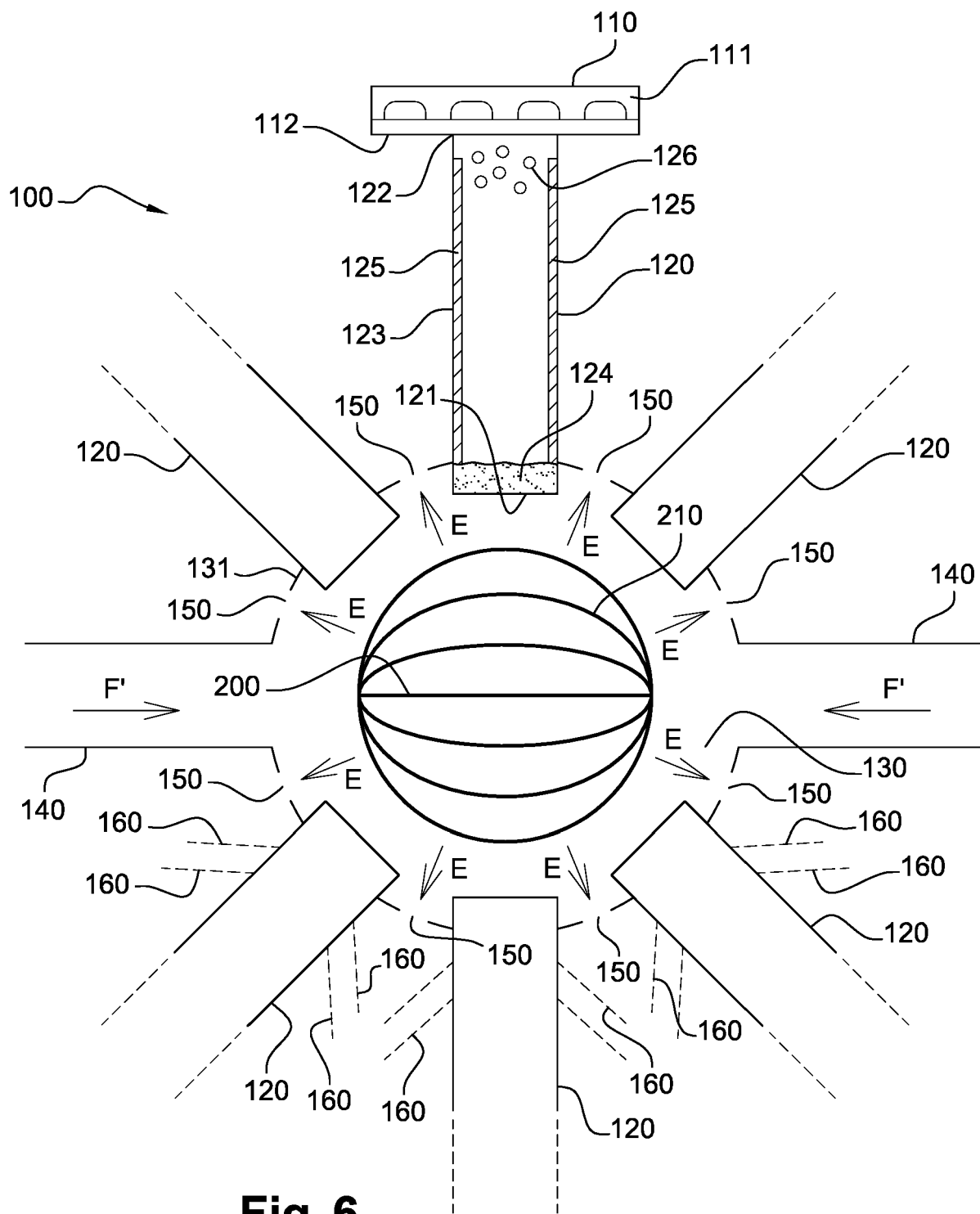


Fig. 6



EUROPEAN SEARCH REPORT

Application Number
EP 16 30 6250

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 976 308 A (FAGHRI AMIR [US]) 11 December 1990 (1990-12-11)	1-10	INV. F28D15/02 F28D15/04
Y	* figures 6,7 *	11-15, 17,20,21	
X	US 2009/151920 A1 (POLCYN ADAM D [US]) 18 June 2009 (2009-06-18)	1-3,5,6, 9	
Y	* figures *	7,10-15, 17,20,21	
X	US 2015/027669 A1 (KOKAS JAY W [US] ET AL) 29 January 2015 (2015-01-29)	1-3,5,6, 9	TECHNICAL FIELDS SEARCHED (IPC) F28D
Y	* figures *	7,10-15, 17,20,21	
A	WO 01/20713 A1 (RAYTHEON CO [US]) 22 March 2001 (2001-03-22)	1-21	
A	US 2012/248907 A1 (CHANG SHYY-WOEI [TW] ET AL) 4 October 2012 (2012-10-04)	1-21	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 March 2017	Examiner Mellado Ramirez, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

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

EP 16 30 6250

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-03-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4976308 A	11-12-1990	NONE	
US 2009151920 A1	18-06-2009	US 2009151920 A1 WO 2009079084 A1	18-06-2009 25-06-2009
US 2015027669 A1	29-01-2015	GB 2516740 A US 2015027669 A1	04-02-2015 29-01-2015
US 2014290918 A1	02-10-2014	CN 104102311 A TW 201440624 A US 2014290918 A1	15-10-2014 16-10-2014 02-10-2014
WO 0120713 A1	22-03-2001	AU 7582300 A CA 2383703 A1 DE 60033165 T2 EP 1218965 A1 JP 4357780 B2 JP 2003509870 A US 7069975 B1 US 2006293086 A1 WO 0120713 A1	17-04-2001 22-03-2001 15-11-2007 03-07-2002 04-11-2009 11-03-2003 04-07-2006 28-12-2006 22-03-2001
US 2012248907 A1	04-10-2012	US 2012248907 A1 US 2014232221 A1 US 2014265669 A1	04-10-2012 21-08-2014 18-09-2014

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82