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(54) **HIGH VELOCITY MIST EVAPORATION**

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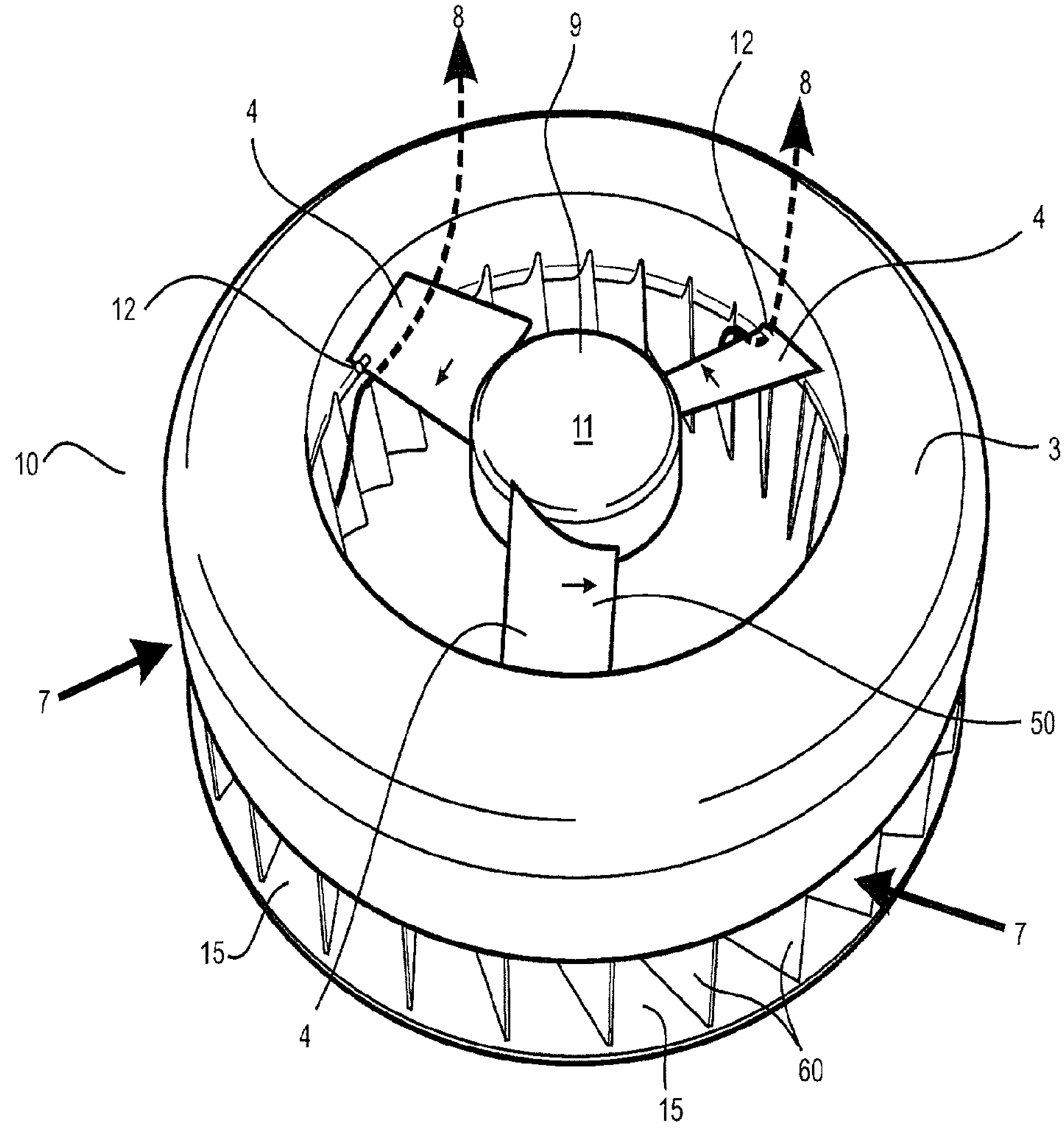
(57) **ABSTRACT**

An evaporation system and method having at least one fan operatively connected to drive means to effect fan rotation, at least one flow path to supply liquid to at least one nozzle to spray a mist of the liquid under centrifugal pressure. Velocity differential between the rotating nozzle(s) and airflow created by the at least one fan provides evaporation of the sprayed liquid. Inlet vanes direct airflow in a direction contra to fan rotation to increase velocity differential. The nozzles can be on fan blades and/or a central disc/hub. The method and system can be used for air conditioning, snow making, desalination or in industrial or commercial evaporators.



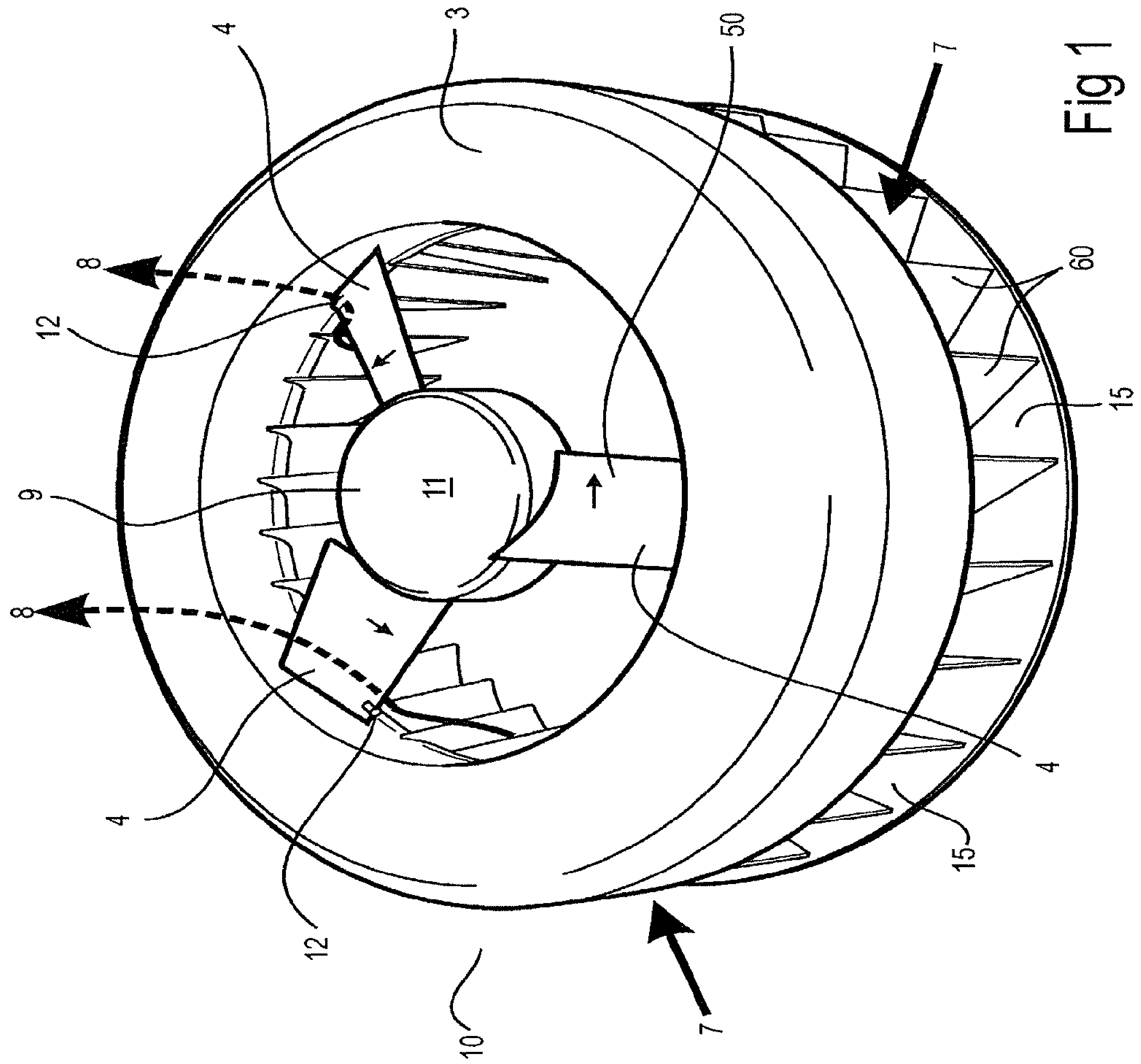


Fig 1

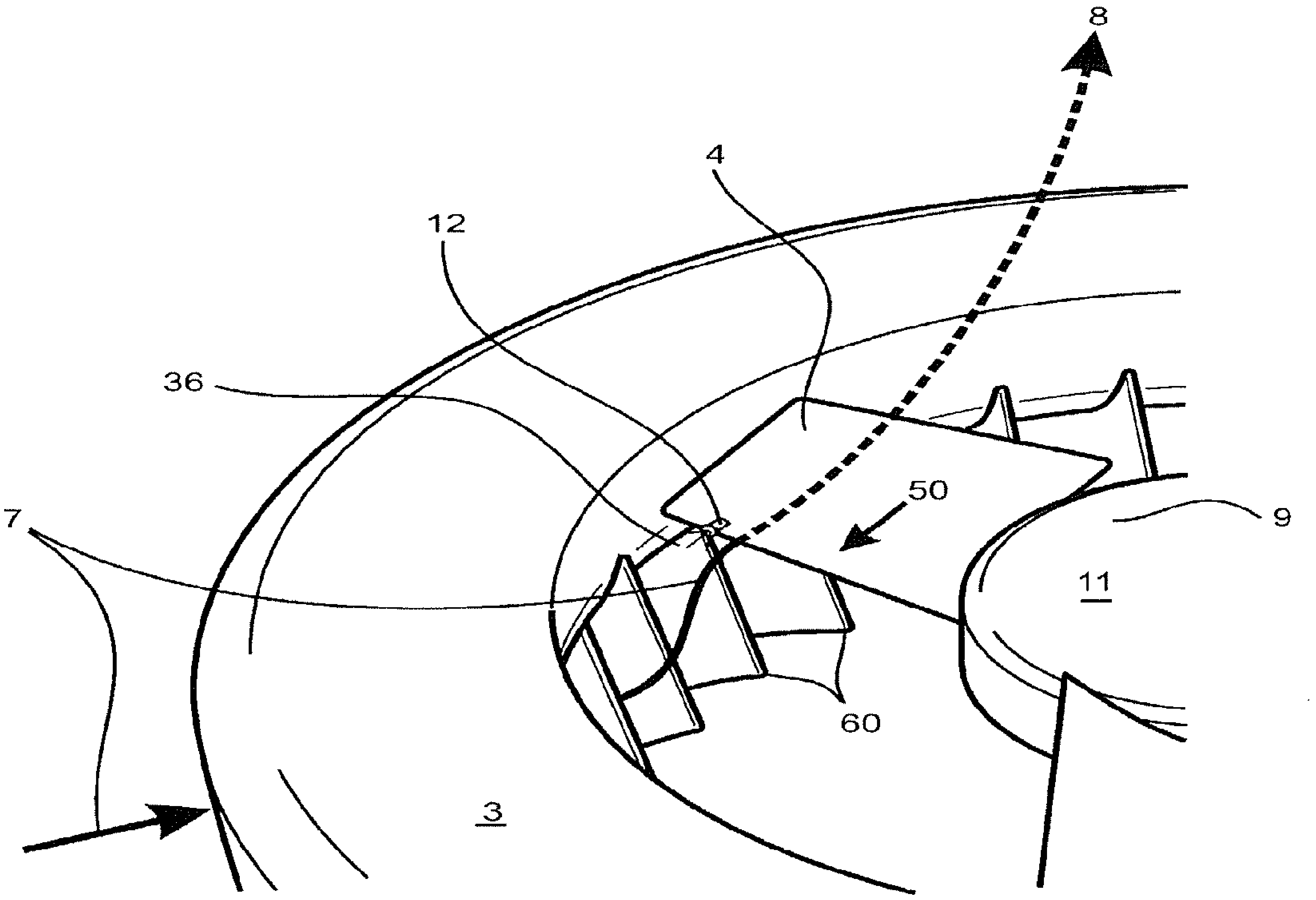


Fig 2

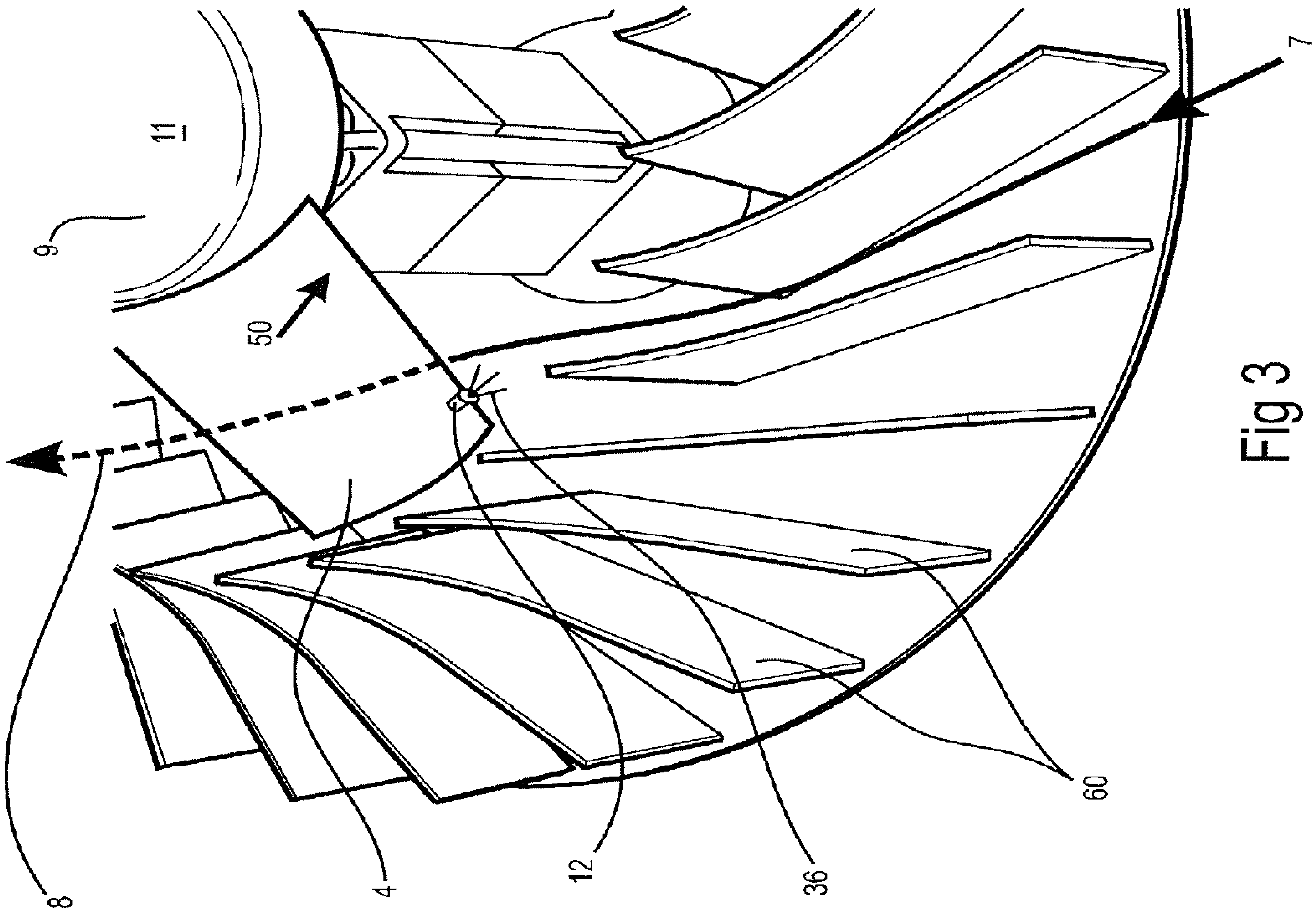


Fig 3

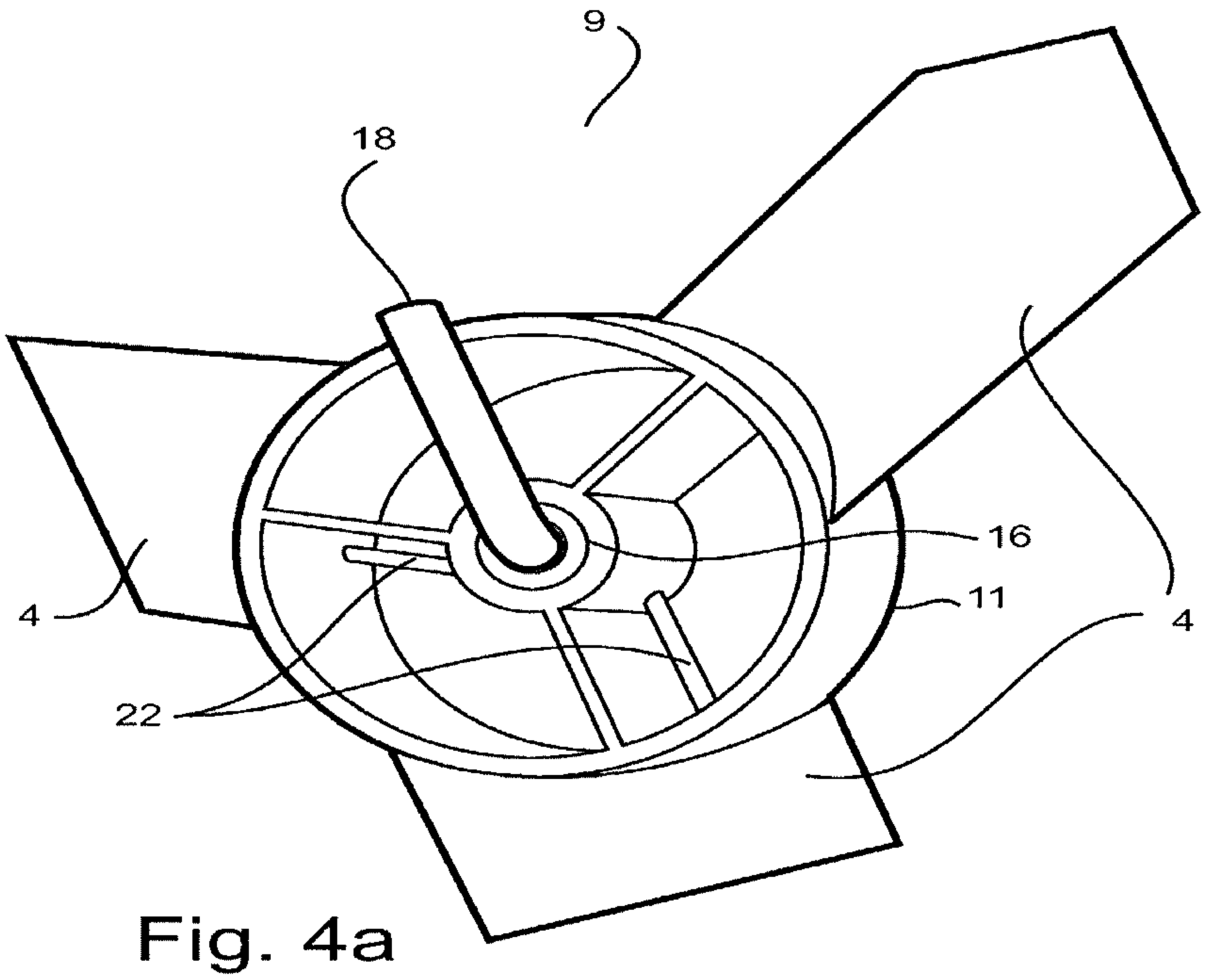


Fig. 4a

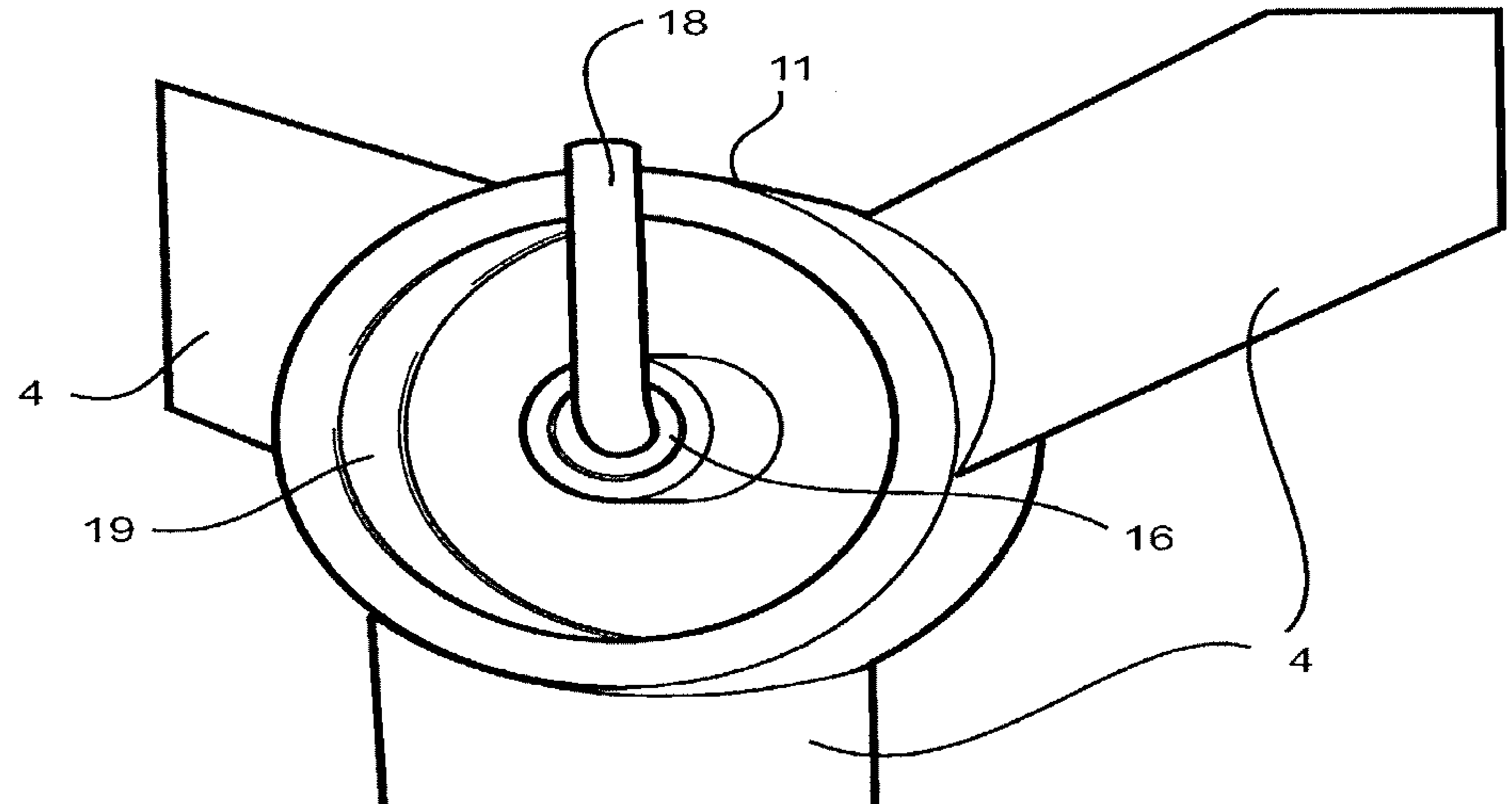


Fig. 4b

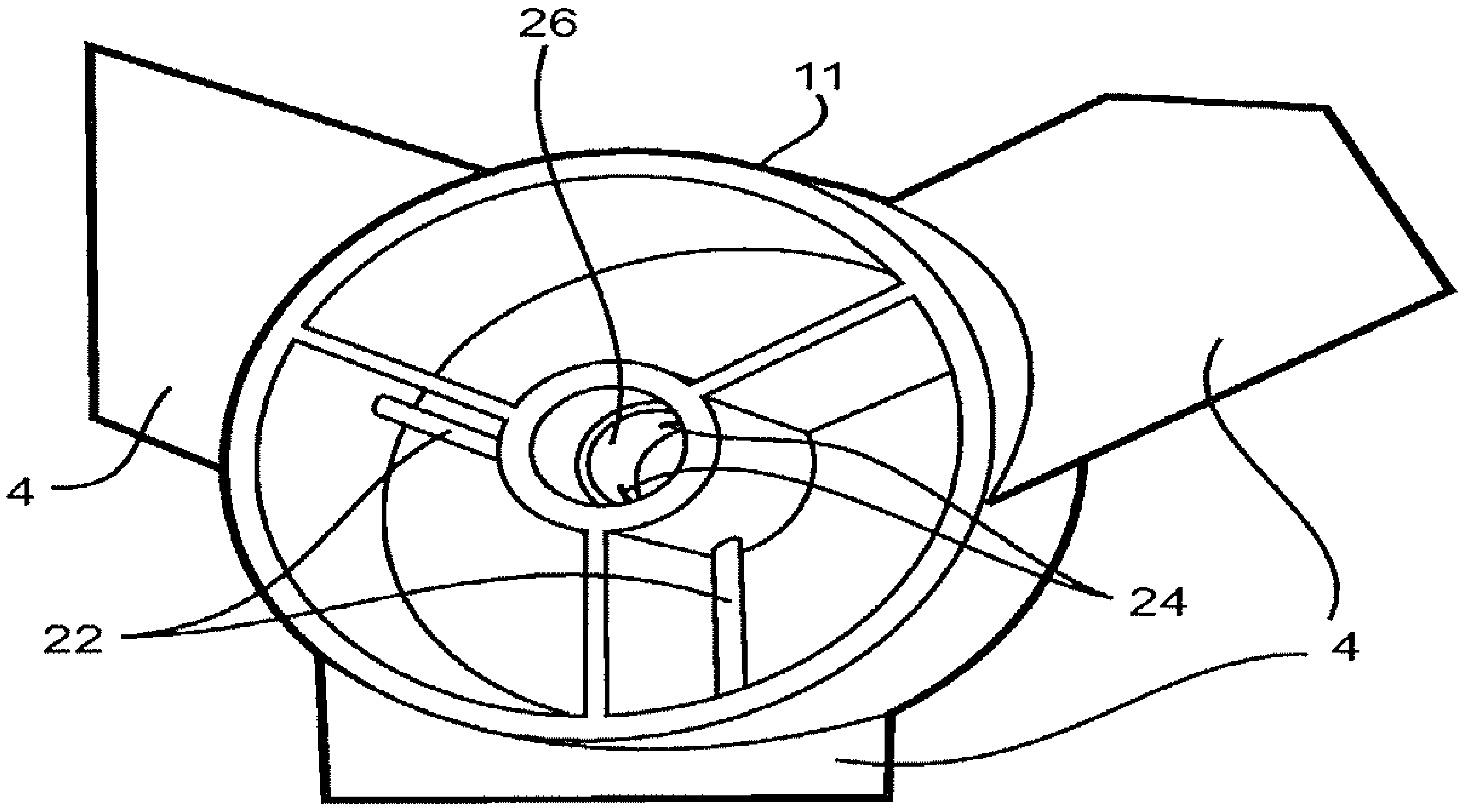


Fig. 5a

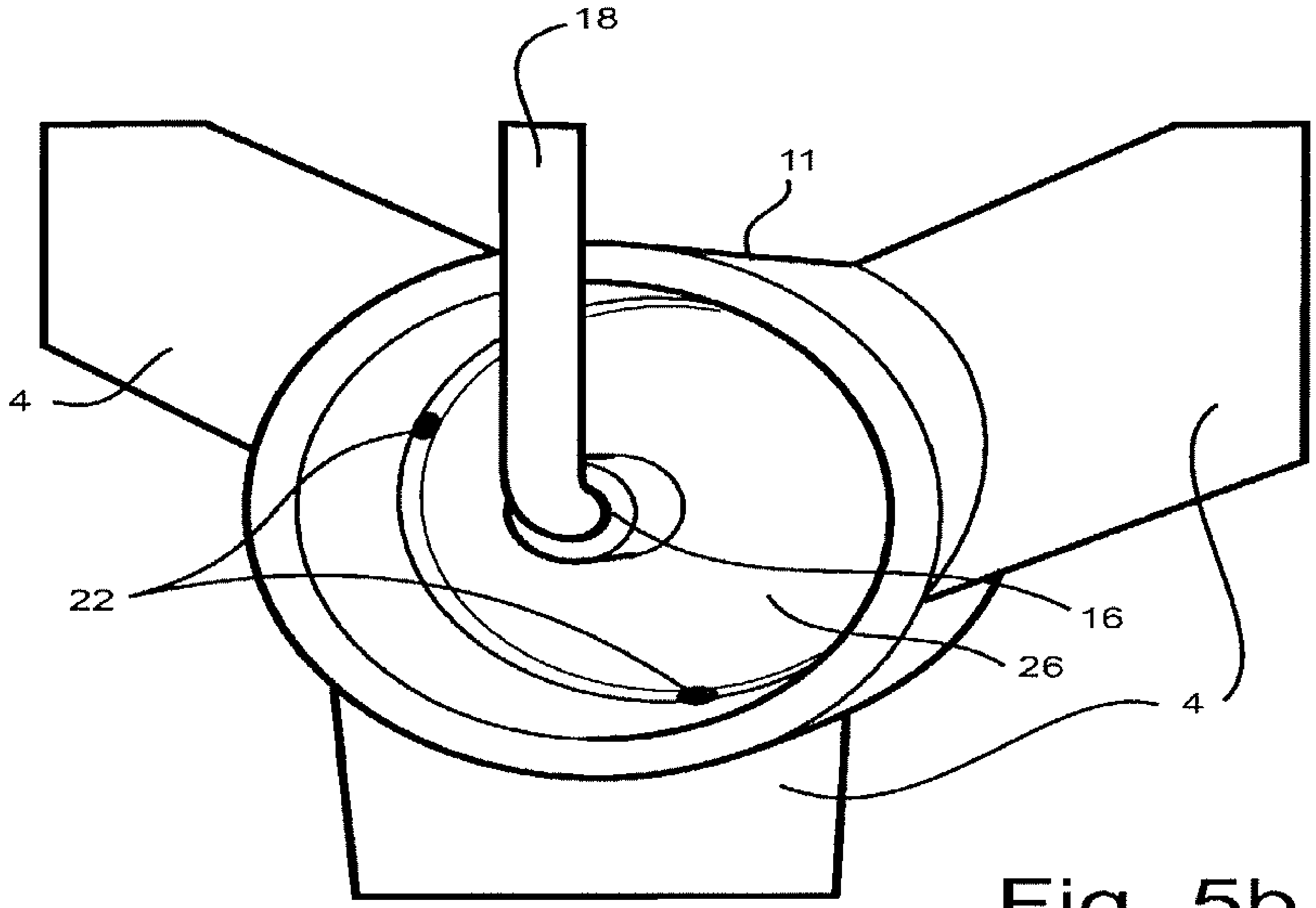


Fig. 5b

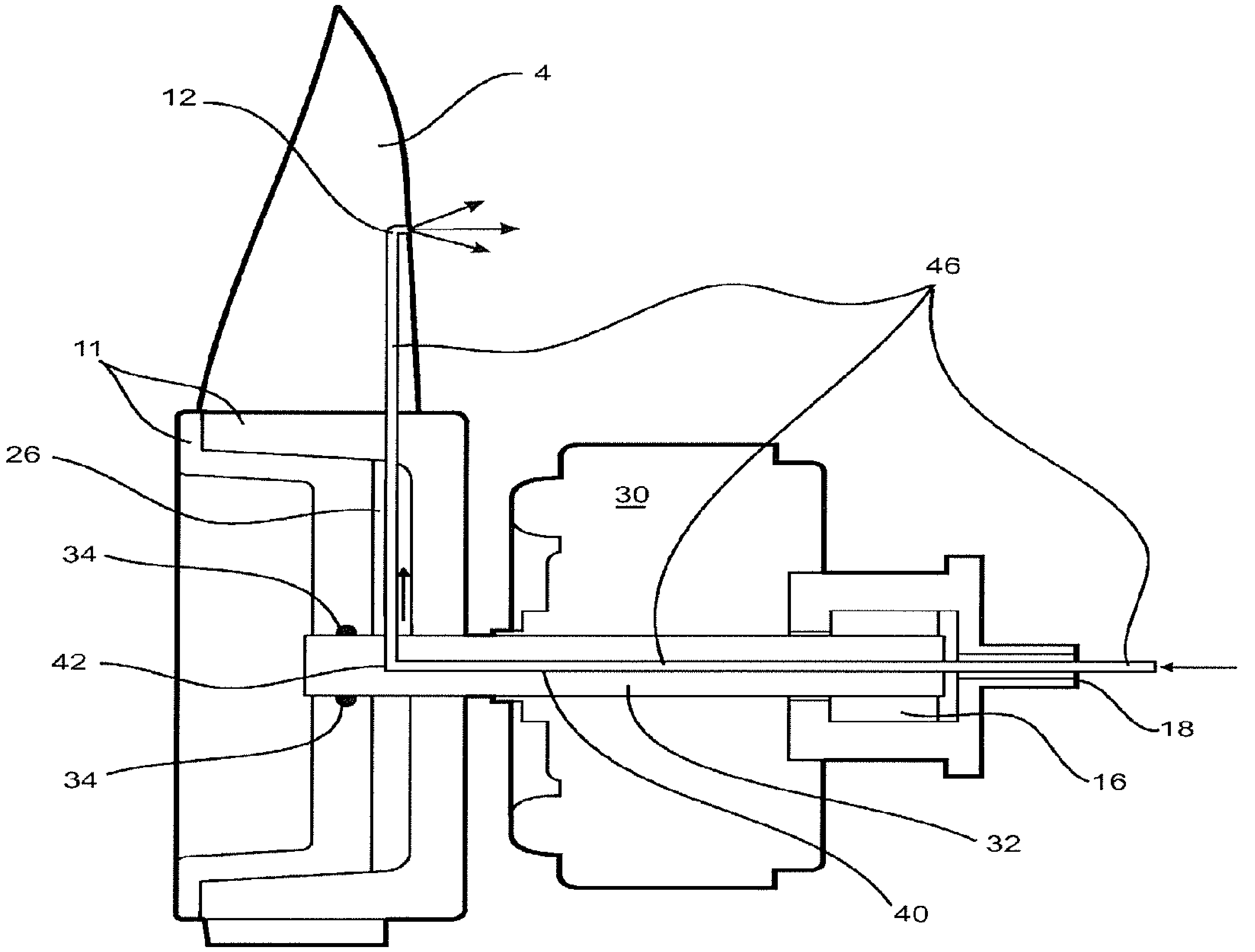


Fig 6

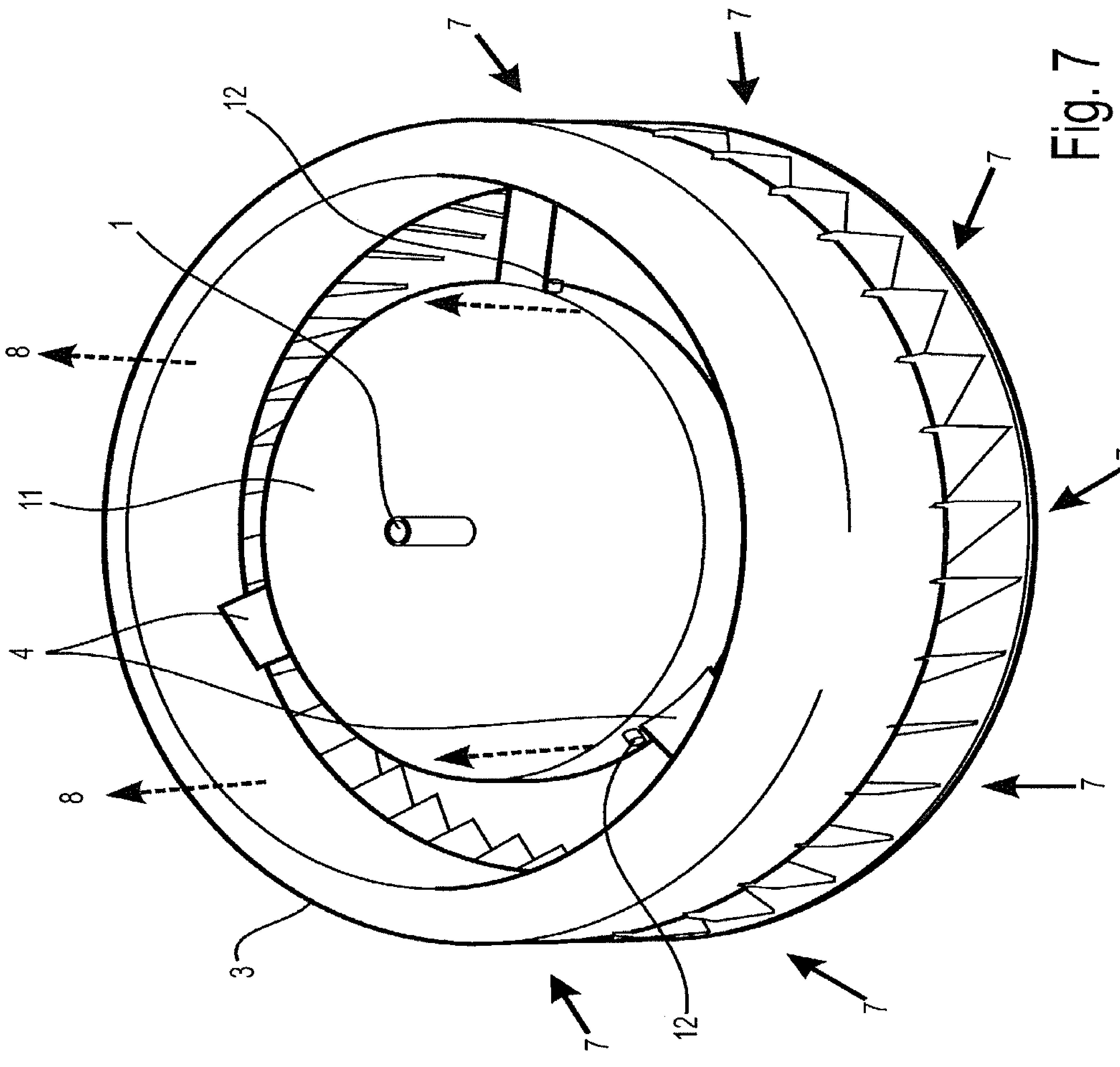


Fig. 7

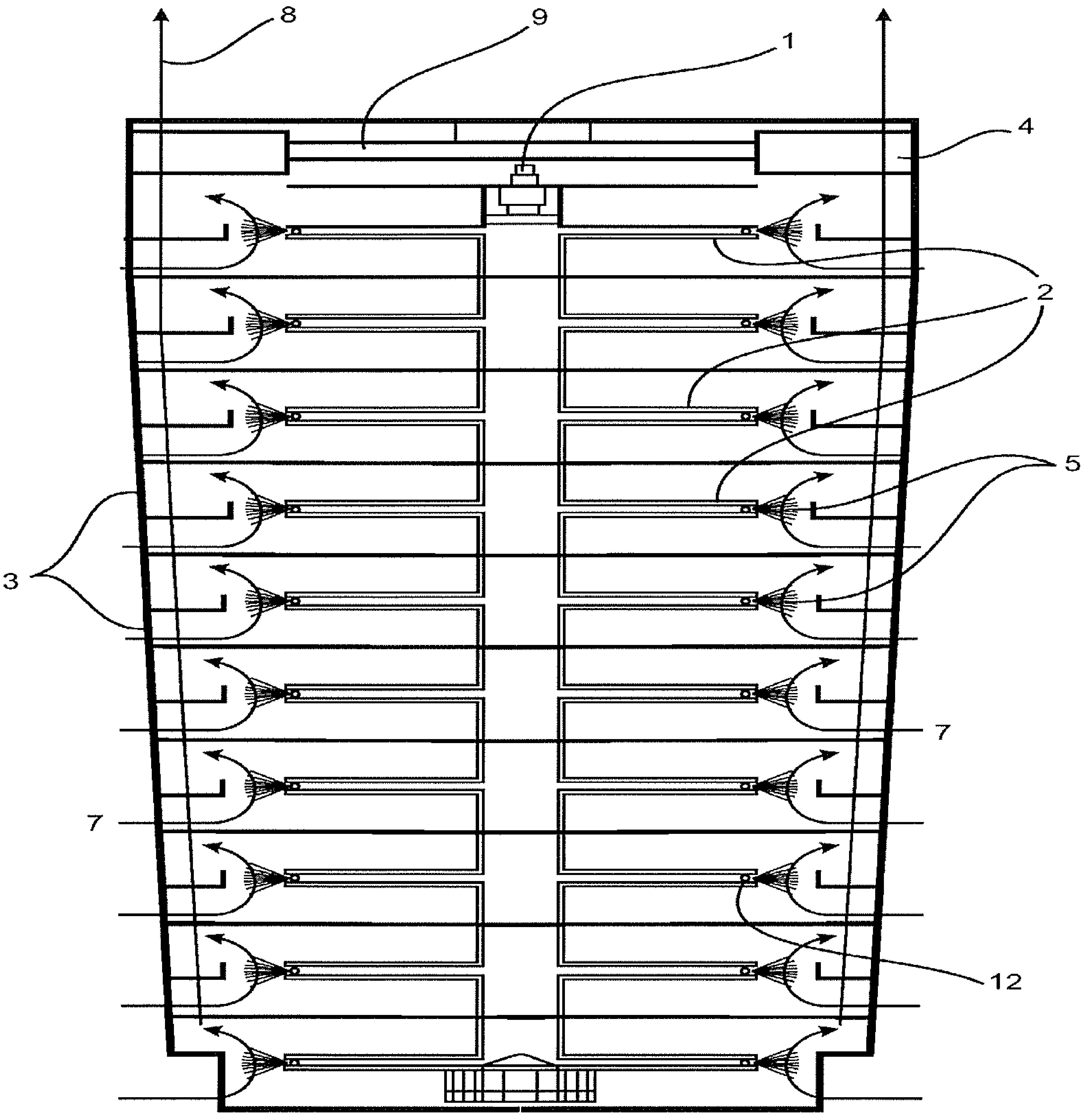


Fig. 8

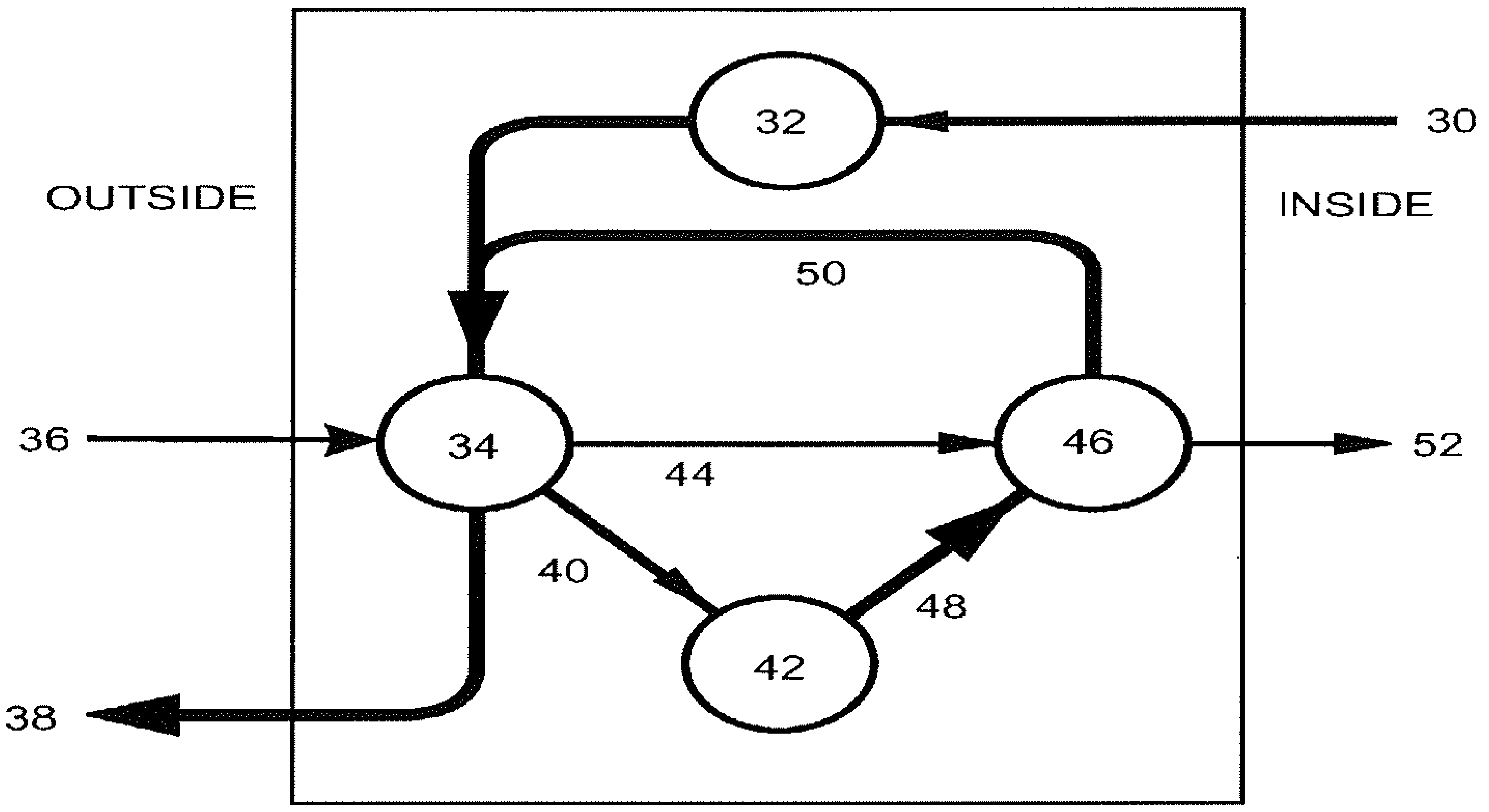


Fig. 9

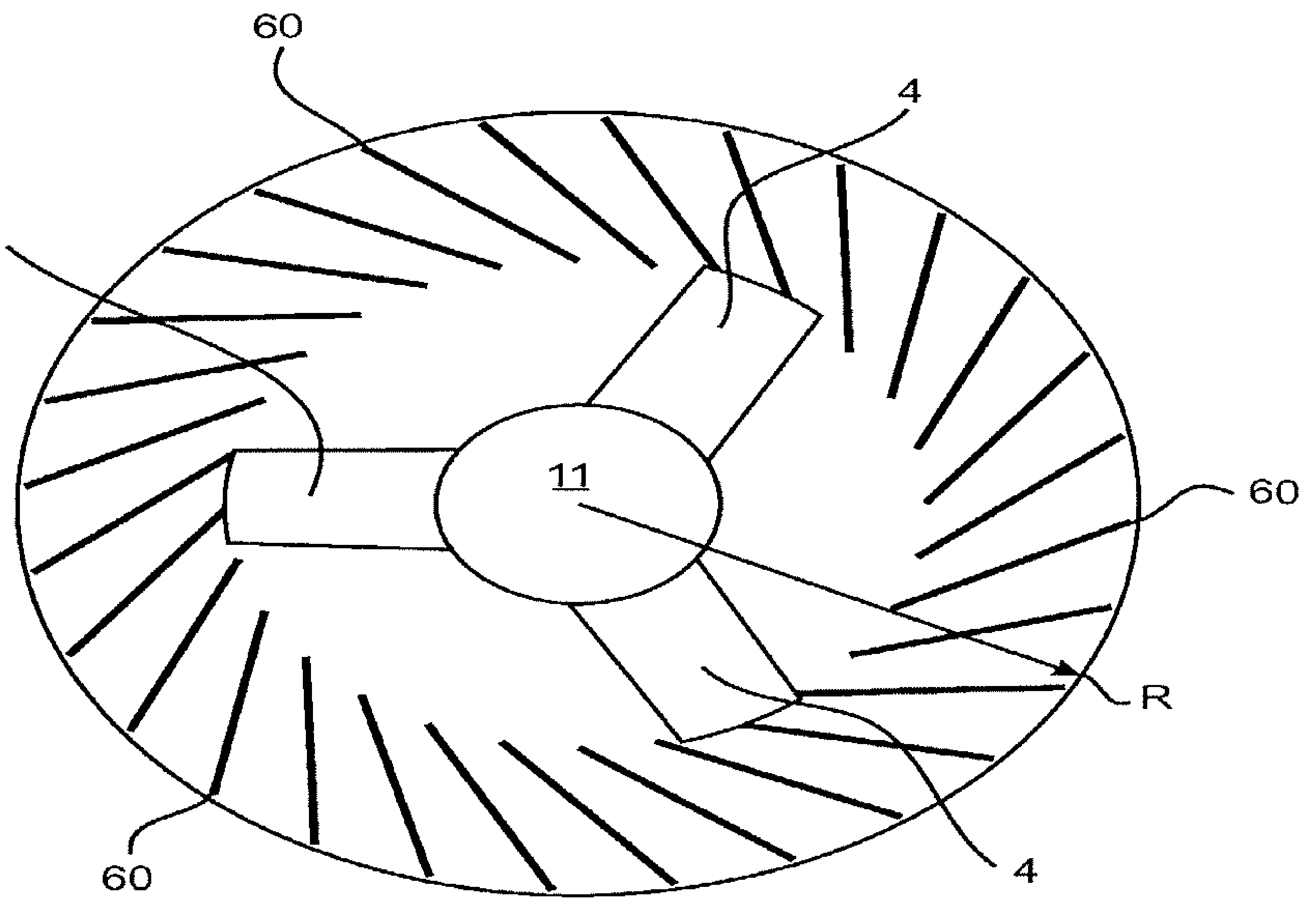


Fig. 10

HIGH VELOCITY MIST EVAPORATION

PRIORITY CLAIM

[0001] This patent application is a U.S. National Phase of International Patent Application No. PCT/AU2012/000289, filed 21 Mar. 2012, which claims priority to Australian Patent Application No. 2011901005, filed 21 Mar. 2011; Australian Patent Application No. 2011903787, filed 15 Sep. 2011; Australian Patent Application No. 2011904545, filed 2 Nov. 2011; and Australian Patent Application No. 2012900069, filed 9 Jan. 2012, the disclosures of which are incorporated herein by reference in their entirety.

FIELD

[0002] Disclosed embodiments relate to evaporative methods, apparatus and systems utilizing high velocity mist evaporation, particularly suited to air conditioning, desalination, industrial evaporators and snow making machines.

BACKGROUND

[0003] Evaporative air conditioners are known for low energy consumption and affordability relative to refrigerative air-conditioners, but poor performance in humid environments. Evaporative air conditioners are also not reverse-cycle; they can only cool, not heat. Evaporative coolers are simple in construction and principle, incorporating a circulation fan, wetted pads and a pump mounted in a system 'box' to deliver coolant, usually water, to wet the pads from a reservoir. They do not use refrigerants like CFCs and HCFCs for the cooling method because they do not have a compressor. They simply rely on evaporation of water from the broad surface area of the wetted pads to cool the air. Known art, by way of conventional evaporative air conditioning systems, consists of a fan that draws air through wetted pads in order to evaporate water from the pads, cooling the air, but increasing the humidity of it.

[0004] Evaporative coolers are, however, popular because they generally only consume a quarter or less of the energy of a compressor air conditioner as power is only used to operate the fan and water pump.

[0005] US 2011/0139005 discloses an air purifier employing a water jet fan system. Water is pumped by an electrically driven water pump and sprayed and scattered by nozzles mounted on the fan. The fan is not driven by the pump motor or any other type of electrical drive or motor. The fan only rotates in the opposite direction to the spray of water through reaction to the water pressure spraying the water. The water spray is used to take particulates out of the air in an air purifying method and not an intentional cooling method. The water jets are direct sprays, and not in the form of a mist because this would not provide sufficient force to drive and rotate the fan.

[0006] U.S. Pat. No. 7,160,469 discloses a water sweetening system. Water sweetening is intended to improve the quality of water, such as in reverse osmosis, distillation and electrodialysis systems. This document teaches a system of centrifugal forces to make water droplets fly at high speeds so as to evaporate and leave behind dissolved salts, while the water condenses elsewhere. No nozzles or fans are employed.

[0007] U.S. Pat. No. 5,395,483 discloses a distillation apparatus that flashes and boils a solution and condensing the resulting steam. A two disc centrifugal distributor rotates and centrifugally pressurises the solution, which is flashed by spraying and is then vaporised by heated conical surfaces, to later be condensed in a central spiral condenser. No evaporative cooling or mist is obtained.

[0008] U.S. Pat. No. 5,439,618 discloses a water atomiser system for cooling, aeration and pollution control. Water sprayed by a jet directly onto blades of a fan which drives rotation of the fan. The rotating fan then atomises the water into fine droplets and forces air through the atomised water. The fan is not motor driven, no misting is created, and any cooling effect, if any, is inefficient.

[0009] U.S. Pat. No. 7,033,411 discloses a centrifugal separator for cleaning a gas from solid or liquid particles. The gas is fed into a rotor surrounded by conical separation discs. Centrifugal force is used to separate the gas from the liquid/solid. No fan is used and no water nozzles are used for evaporative cooling.

[0010] In addition to the above, Legionnaires disease is a known problem of evaporative systems, although generally only rarely in large cooling towers and virtually never in domestic systems. However, not all establishments accommodate evaporative coolers; building codes sometimes disallow these for health purposes.

[0011] With the aforementioned in view, it is desirable of the disclosed embodiments to provide a method, apparatus or system for effecting evaporation or cooling, such as for air-conditioning.

SUMMARY

[0012] In at least one form, the disclosed embodiments provide an evaporative method incorporating nozzles located in fan blades of a fan, wherein centrifugal pressure from spinning the fan pressurizes the liquid to form a mist discharge from the nozzles that is rapidly evaporated via a relatively high differential between the nozzle velocity and the air velocity created by the fan.

[0013] The technology applies to air conditioning principally but can also apply to other applications including desalination, industrial evaporators and snow making machines.

[0014] Disclosed embodiments may also incorporate a two-stage method to achieve lower temperatures than traditional direct evaporation equipment, such as air conditioners.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] In order that the disclosed embodiments may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings in which:

[0016] FIG. **1** shows an evaporation apparatus according to at least one disclosed embodiment;

[0017] FIG. **2** shows a section in close up of the embodiment shown in FIG. **1**;

[0018] FIG. **3** shows a section of the evaporation apparatus of FIGS. **1** and **2** with cowling removed and showing the side air flow directing vanes;

[0019] FIG. **4***a* shows a front view of part of a fan showing a fan hub with central liquid supply tube and seal, and liquid distribution tubes radiating from the central hub to the bases of the blades according to at least one disclosed embodiment;

[0020] FIG. **4***b* shows part of at least one disclosed embodiment with a cover over a hollow fan hub chamber to supply liquid to the feed tubes;

[0021] FIG. **5***a* shows the embodiment of FIG. **4***a* with the liquid supply tube and seal removed;

[0022] FIG. **5***b* shows the embodiment of FIG. **4***b* with hub cover removed to show the hub chamber and openings leading to flowpaths through the blades or to the periphery of the hub;

[0023] FIG. **6** shows a part sectional view of a fan and motor assembly with rear liquid supply through the motor spindle to the fan blades according to at least one disclosed embodiment;

[0024] FIG. **7** shows an evaporative apparatus with nozzles mounted at the edge of the central spinning fan hub with mist ejection from the nozzles into the turbulent airstream wake behind the fan blades, and side entry air flow directing vanes according to another disclosed embodiment;

[0025] FIG. **8** shows yet another disclosed embodiment as a stacked system with multiple spinning discs/hubs/nozzles;

[0026] FIG. **9** shows a dual stage evaporation air conditioning system according to at least one disclosed embodiment; and

[0027] FIG. **10** depicts at least one disclosed embodiment of a system with cowling removed to show the arrangement of inlet vanes.

DETAILED DESCRIPTION OF THE DISCLOSED EMBODIMENTS

[0028] At least one disclosed embodiment provides an evaporation apparatus including a multi bladed fan operatively connected to a drive means to effect rotation of the fan, at least one flow path to supply the liquid to at least one nozzle on the fan, the at least one nozzle spraying the liquid therefrom through centrifugal pressurisation when the fan is rotating, and velocity differential between the rotating nozzle(s) and airflow created by the fan providing evaporation of the sprayed liquid.

[0029] Another disclosed embodiments provides a corresponding method of evaporation utilizing pressurised liquid flow through nozzles on a fan, the method including rotating a fan; providing liquid under pressure to one or more of the nozzles on the fan; discharging the liquid from the nozzles as a mist; and evaporating the mist via a difference between nozzle velocity arising through rotation of the fan and air velocity created by the fan.

[0030] The method may further include rotating a multi bladed fan, providing a conduit along or through one or more of the fan blades to one or more nozzles on one or more of the fan blades to supply liquid to the nozzle(s), centrifugally pressurising the liquid supplied to the nozzle(s) by rotation of the fan, and spraying the liquid as a mist from the nozzle(s) by the centrifugal action and velocity of the nozzle(s) relative to airflow created by the fan.

[0031] Distribution of the liquid may be from a central hub of a respective fan through flow paths on or inside the fan blades to the nozzles.

[0032] Air may be introduced to the at least one fan via inlet vanes disposed circumferentially around the at least one fan.

[0033] Incoming airflow to the fan(s) may be guided (such as by the inlet vanes) in a direction contra to a direction of rotation of the fan(s).

[0034] Disclosed embodiments rapidly evaporate mist discharged from the nozzle(s) via a relatively high differential between the nozzle velocity and the air velocity.

[0035] Each fan blade may include at least one of the nozzles. Single or multiple nozzles may be provided on each blade. Alternatively, every other blade in a fan with an even number of blades (4,6587 . . .) may include one or more of the nozzles.

[0036] Advantageously, the fan blades include the mist emitting nozzle(s) spun to induce centrifugal fluid pressure in the nozzles to create a fine mist, resulting in rapid evaporation via the high velocity mist exit speed into a refresh air stream.

[0037] The at least one nozzle may be located at or adjacent a fan blade tip. In this way, the relatively high tip speed of the fan with respect to the rest of the rotating fan ensures the velocity of the nozzle(s) is therefore high; whereas, the actual refresh airflow velocity induced by the fan blades is relatively low to save energy.

[0038] It is important to comprehend that the velocity of the blade tips of a typical fan, particularly a vane axial fan, is generally about seven times (7×) faster than the actual airflow induced by the fan. This core principle allows disclosed embodiments to achieve high evaporation rates.

[0039] At least one disclosed embodiment relates to an evaporation method incorporating the spinning of nozzles, such that mist discharged from the nozzles is rapidly evaporated via pressure differential between high nozzle velocity relative to slower air velocity.

[0040] Mist emitting nozzles are mounted at or towards the tips of fan blades such that the spinning fan induces centrifugal fluid pressure in the nozzles to create a fine mist through the nozzles, resulting in rapid evaporation via the high velocity mist exit speed into a refresh air stream.

[0041] The velocity is achieved by the high nozzle velocity at the periphery of the fan blades, whereas the actual refresh airflow velocity induced by the blades is relatively low to save energy.

[0042] Although many fan types can be used in the disclosed embodiments, it has been found that the vane axial fan type offers an excellent basis from which to extract high performance. Other fan types are envisaged to fall within the scope of the disclosed embodiments.

[0043] Vane axial fans offer some of the highest efficiencies of all fan types for moving air. In addition, the shape and configuration of vane axial fans, i.e. relatively flat compared to their diameter, offers an ideal layout for use in the disclosed embodiments.

[0044] The drawings and description in this specification disclose embodiments utilizing vane axial fans. In particular, the vane axial fan configuration allows for guided air inlet vanes to direct refresh/incoming air over the nozzle outlets and onto the blades such that the airflow is contra to the blade/nozzle direction. This helps to maximize velocity differential between the air flow speed and the nozzle speed, and therefore maximizes evaporation of the mist ejected from the nozzles i.e. the blade direction and refresh/incoming air are in opposite directions and yet the air flow rate of the fan is still also maximized.

[0045] It has been found that angled inlet vanes help to maximize overall performance of the evaporative device, and actually also slightly increase vane axial fan performance.

[0046] Compared to a traditional vane axial fan where incoming air and outgoing air follow a generally straight through flow (i.e. following the fan axis), guided inlet vanes of one or more disclosed embodiments induce the incoming air from the side (perpendicular to the vane axial fan rotation axis) and direct that air in, around and onto the blades, to then follow a traditional axial flow outlet path and away from the axial fan.

[0047] It has been found that the guided side vanes of disclosed embodiments increase fan airflow rates by about 7% over traditional straight-through vane axial fan performance. This not only improves fan efficiency but also provides the ability to mount vane axial fans flush on a wall. This has not been possible prior to the present invention because vane axial fans (and axial fans in general) normally require mounting a significant distance out from a wall to allow a straight-in (axial flow) air flow entry. Consequently, guided side vanes directing air to vane axial fans open market opportunities and applications for flush wall-mounted fans that did not previously exist.

[0048] Another disclosed embodiment provides a central fan hub with the nozzles emitting a mist out from the edge of the fan hub into the fan blades' air streams (the blades extending out from the central fan or hub).

[0049] Spinning nozzles of the disclosed embodiments may be located on a fan hub supporting fan blades or near the end of the blades themselves.

[0050] In the latter instance, liquid may be distributed out via centrifugal force from the central hub through flow paths in the inside of the fan blades to the nozzles located at or near the ends of the fan blades.

[0051] The velocity of the blades near the tips is high (typically about 7 times the velocity of the induced airstream) which results in rapid evaporation of the liquid on ejection from the nozzles as a fine mist, created due to the centrifugal pressure of the spinning fan blades.

[0052] The liquid may enter the fan from the front (non-motor side) or the rear (motor side) via a flow path tube inside the motor shaft. The latter option (fluid entry from the rear or motor side) has advantages of not requiring alignment of the inlet tube and a neater appearance.

[0053] Disclosed embodiments may incorporate liquid supply via the motor shaft, with fluid flow entering the motor shaft inlet tube hole, travelling through the hollow shaft to the motor shaft fluid dispersal holes, through the fan hub fluid dispersal chamber, distributing out through the radial fluid dispersion tubes within the fan blades and then out through the nozzles located in the region of the blade tips. This represents an extremely effective system that to all intents and purposes appears as a conventional fan.

[0054] The nozzles can be positioned towards the blade tips or far enough out on the disk to be effectively in the blade tip radius area. Centrifugal pressure and nozzle velocity are higher the further out along the radius from the rotation axis that they are positioned (for a given RPM). Therefore, the smaller the droplet size and higher the evaporation rate. The nozzles may be positioned towards the periphery of the disc, hub or fan blades, such as in the outer half of the radius of the fan from the central axis.

[0055] In summary, performance basically relies on nozzle velocity. If revolutions per minute (rpm) increase, nozzle velocity increases, which in turn increases centrifugal pressure. Higher nozzle pressure in turn creates a finer mist which, in combination with the higher velocity increases evaporation.

[0056] Advantages of the disclosed embodiments for, in particular, air conditioning:

[0057] Not as dependent on RH levels, therefore better performance in humid environments.

[0058] Method fluid is not restricted to clean freshwater but can also be saltwater or even wastewater.

[0059] Much less energy than compressor air conditioning systems.

[0060] Smaller, lighter, simpler and cheaper than traditional evaporative systems.

[0061] No pads to foul or change.

[0062] No large wetted-pad roof boxes required.

[0063] More easily located in cooler, more efficient locations to improve efficiency even more.

[0064] No pump-required.

[0065] Lower air flow rates are required compared to traditional wetted pad evaporative systems, resulting in lower energy consumption.

[0066] For the sake of convenience, the disclosed embodiments will hereinafter be described with particular reference to air conditioning, although the disclosed embodiments apply just as well to desalination, industrial evaporation for pharmaceuticals etc and snow making machines, but it is to be understood that the disclosed embodiments are not limited thereto.

[0067] While the disclosed embodiments are particularly applicable to air conditioning, and this description is focussed on that application, the same embodiments can also be used as the evaporative front-end for a desalination or wastewater treatment system/method and in snow making machines, negating the need for pumps to pressurize the nozzles.

[0068] It is firstly worthwhile giving some general background to the concept behind the disclosed embodiments.

[0069] A spinning disk is an efficient mechanical device since it is essentially a wheel. The power required to spin an atomizing disk is low compared to having to use pumps to pressurize the Reverse Osmosis (RO) elements in a conventional desalination system. In a desalination system/method, centrifugal force induces fluid pressure in nozzles to create fine seawater droplets of mist (typically 10-50 micron). Water is rapidly evaporated from the salt in each droplet by the high velocity exit 'airstream' then can be condensed into freshwater by conventional means. The pressure at the periphery of the disc/hub can be determined by the known equation for centrifuges, the pressure being described by the following equation:

$$P=\rho\cdot\omega^2\cdot R^2/2$$

Where

[0070] ρ=density of the fluid

[0071] ω=angular velocity at the periphery

[0072] R=radius

[0073] The only losses in the spinning disk are in the bearings & wind resistance, both of which are negligible. In other words, it is very close to 100% efficient to create the required pressure via the centrifugal means of spinning a disk. The methods of spinning the discs/hub to obtain the required centrifugal-induced fluid pressure in the nozzles can be via electricity (AC mains or DC battery) or direct mechanical drives from wind or wave sources.

[0074] It is generally understood that "saturated" air is holding as much water vapour as it can and that warm air holds more water vapour than cool air. This implies that once the air has reached saturation it won't "accept" more water by evaporation. This is not strictly correct, as it is possible to continue evaporation even when the air is fully saturated in a condition referred to as super-saturation.

[0075] Smaller water droplets have larger surface area relative to volume so it is then easier for one of these water molecules to escape the intermolecular forces trying to keep it in the droplet. Molecules in motion have more energy than those at rest, and so the stronger the flow of air, the greater the evaporating power of the air molecules. The particles of a liquid attract each other. So when a particle leaves the surface, there is a force from all the surface particles trying to pull it back. However, if it is travelling at high velocity it can escape from this force. Particles with a high kinetic energy can escape—or evaporate.

[0076] Using heated air to, in turn, heat water droplets to induce evaporation is a highly inefficient heat transfer method. This method requires the heated air molecules to transfer heat to the droplets to induce water molecules to escape the intermolecular forces trying to keep them in the droplet.

[0077] Disclosed embodiments aim to induce the water molecules to escape using high velocity and turbulence to rip the droplets apart, inducing evaporation.

[0078] Given the above basic principles, it is apparent that heat is not the only option available to induce evaporation and that the underlying conditions shown on typical psychrometric charts are not restrictive to evaporation rates under conditions other than ‘normal.’ In other words, it is possible to supersaturate the air considerably under certain conditions. The conditions utilized by the disclosed embodiments induce super-saturation and very high levels of evaporation are created via turbulent, high velocity mist exit speed from the nozzles. The large velocity differential between the nozzles and airflow is able to create such conditions in a simple and highly efficient manner.

[0079] A summary of the spinning nozzle method of at least one disclosed embodiment is as follows:

[0080] Air feeds into the cowling that houses the fan via the air inlets and the method fluid (seawater, wastewater or freshwater etc) feeds into the fluid inlet at the core/axis of the fan disk, hub or motor shaft.

[0081] The disk/hub spins at high RPM, inducing centrifugal fluid pressure to create a fine mist of droplets out through nozzles spinning at high velocity at the periphery of the disk/hub or near the tips of fan blades extending out from the central disk/hub. This is a highly efficient means of spraying the mist because the mist ejects into a high velocity ‘airstream’ without having to use power to actually create a high velocity airstream as such. That is, although power is used to rotate the fan to create an airstream, that airstream does not need to be high velocity. It is the differential between the hub/blade speed at which the mist is sprayed and the air flow over the blades that effectively results in a high velocity airstream.

[0082] In addition to the nozzle speed, a separate contraflow airflow to refresh air over the nozzles is created either by blades mounted on the disk(s) or via a separate fan that feeds a multitude of disks.

[0083] The high nozzle velocity mist discharge in combination with air turbulence evaporates the majority of the mist droplets very soon after ejecting from the nozzles and the evaporated freshwater exits as cooled vapour.

[0084] Conventional evaporative air conditioning systems are generally almost all single stage. In other words, there is only one cooling stage to the cycle so the single air stream passes through the wet channels of the pads only once. It is therefore not possible to reach a temperature lower than ‘wet bulb’. However, as a rule of thumb, pre-cooling the air ten degrees will cause a three degree decrease in the output temperatures of an evaporative air cooler.

[0085] To make use of this effect, disclosed embodiments can utilize a two stage cooling method. Using two evaporative systems of the disclosed embodiments and two heat exchangers, lower cooling temperatures can be reached than with single stage evaporative systems, enabling the disclosed embodiments to better compete with compressor cooling systems. In addition, this two stage option does not place moist air into the building like traditional evaporative systems; the cooled air does not contain extra moisture as higher humidity air is expelled. This means that disclosed embodiments exchange the inside air with fresh, cooled air; something that compressor systems do not do.

[0086] Evaporation using at least one disclosed embodiment also provides salt-water or grey-water evaporative air-conditioning. Because of the very high evaporation rates, significant temperature drops and heat pumping take place even using seawater or grey-water as the method fluid, not requiring clean fresh water.

[0087] FIG. **1** is an example of a disclosed embodiment of an evaporation system.

[0088] An evaporation system **10** includes a fan **9** with a hub **11**. In this disclosed embodiment a vane axial fan is used. A cowling **3** partially covers air inlet vents **15** disposed around a periphery of the system. Vanes **60** are angled with respect to a radial direction from the centre of the system to define the air inlet vents. Liquid is supplied to the fan via a liquid supply system (not shown) from the rear. Liquid flows in a flow path into the fan, through the fan blades **4** themselves and ejects through nozzles **12** in the fan blade tip regions. Fan blade tip regions can be at or near the blade tips. However, it will be appreciated that the nozzles need only to be disposed towards the tip regions of the blades. Pressure in the liquid at the nozzles prior to ejection increases the further the nozzles are disposed to the tip regions, for a given rpm. The pressure increases due to increase in centrifugal forces towards the tips of the blades, and blade tip rotation velocity is higher the further along the radius from the rotation axis. Thus, smaller droplets and higher evaporation rates can be achieved. The spinning nozzles **12** located near the fan blade **4** tips, spinning around inside the cowling **3** with the liquid distributed out internally via centrifugal force from within the central hub **11** through fluid flow paths located out through the inside of the fan blades **4**. Fan blades **4**, blade spinning direction **50**, warm air-in direction **7** guided by inlet vanes **60** and cool air-out direction **8** following evaporation of the mist emitted from the nozzles **12**.

[0089] FIG. **2** is a close up of a section of the embodiment of the system disclosed and described in FIG. **1**. The liquid flows into the rear of the fan through the motor spindle/shaft and out via the central hub **11** through hollows in the inside of the fan blades **4** and is then ejected through nozzles **12** located near the fan blade tips to become a mist **36**, blade spinning direction **50**, warm air-in direction **7** guided by inlet vanes **60** and cool air-out direction **8** following rapid evaporation of the mist **36** from the nozzles **12**.

[0090] FIG. **3** is an example of an embodiment disclosed and described in FIGS. **1** and **2**. The cowling has been removed to show some of the inlet vanes **60**. Again, the liquid flows in from the rear through the motor shaft and is dispersed out through the central hub **11** through flow paths or conduits in the inside of the fan blades **4** and then ejected through nozzles **12** located near the fan blade tips to become a mist **36**.

Also shown are the direction of rotation (blade spinning direction) **50**, warm air-in direction **7** guided by inlet vanes **60** and cool air-out direction **8** following rapid evaporation of the mist **36** from the nozzles **12**.

[0091] FIG. **4***a* is another disclosed embodiment compared to that in FIGS. **1**, **2** and **3**. FIG. **4***a* shows the front supply of liquid to the fan **9** via a supply tube **18** entering the central hub **11** of the fan **9** through the central hub flange. The liquid flows through the fan blades themselves and ejects through nozzles in the fan blade tip regions. The liquid is distributed out from the front-side inlet tube **18** via centrifugal force through the inner section of the three-blade fan and central hub **11** through a hollow central chamber in the flange to radial liquid dispersion tubes **22** leading to the hollow internal fluid paths inside the fan blades **4** and out to the nozzles located in the region of the blade tips.

[0092] FIG. **5***a* is a similar view to that of FIG. **4***a* but with the front inlet tube **18** and the rotary liquid seal **16** removed to show the fluid dispersal chamber **26**. After flowing through the inlet tube **18**, liquid enters the fluid dispersal chamber **26** and distributes out through the three radial liquid dispersion holes **24** into the liquid radial dispersion tubes **22** inside the three fan blades **4** and out to the nozzles located in the region of the blade tips. Also shown is the hub **11** and three fan blades **4**.

[0093] FIG. **4***b* shows an alternate construction technique to FIG. **4***a*, featuring a larger internal fluid dispersal chamber (without dispersal tubes **22** as in FIG. **4***a*). It therefore includes a two-part hub **11** with a hub cover **19** in place, rotary seal **16** which prevents the liquid escaping from the front of the rotating hub, fluid inlet tube **18** and blades **4**.

[0094] FIG. **5***b* shows the same view as FIG. **4***b* but with the hub cover **19** removed to show the rotary seal **16**, internal hub chamber **26** with the open holes of the blade liquid dispersion tubes **22** that become flow-paths within the blades **4**.

[0095] In use, as the hub/fan rotates, liquid supplied to the hub becomes pressurized by centrifugal force at nozzles on the blade tip regions and/or hub periphery, to thereby spray as a mist out of the nozzles and into the airstream created by the rotating fan.

[0096] FIG. **6** shows another disclosed embodiment. FIG. **6** depicts a close cross-section representational view of a 'split-half or 'cutaway' drawing of a system of the disclose embodiments incorporating a fluid inlet feed via the motor shaft/spindle **32**. It shows the total flow path **46** though the system (of one example blade), being the inlet tube **18**, motor shaft centre hole **40**, motor shaft **32**, motor shaft fluid dispersal holes **42**, fluid dispersal chamber **26**, distributing out through the radial fluid dispersion tubes inside the fan blades **4** and out through the nozzles **12** located in the region of the blade tips. Also shown is the two-part hub **11**, motor **30**, static O-Ring seals **34** and rotary fluid seal **16**.

[0097] FIG. **7** shows an evaporative system with nozzles **12** mounted at the edge of the central spinning disc/hub **11** with mist ejection from the nozzles into the turbulent airstream wake behind the blades **4**. It shows a typical representational view of a central disk/hub **11**, front-side (non-motor shaft side) feedwater inlet point **1**, nozzles **12** mounted at the periphery of the spinning disk/hub **11** and behind the blades **4**, such that mist is emitted from the nozzles **12** when the disk is spun (anti-clockwise in this embodiment), air inlets **7**, cowling **3**, depiction of the airflow path through the system beginning with warm air in through the side inlets **7** and finishing with cool air vertically out **8**.

[0098] FIG. **8** is a further disclosed embodiment, being a stacked system with multiple spinning disks/nozzles (as per FIG. **7**) and only one fan **9**. It shows an example cross-section view of a bank of ten horizontally oriented discs/hubs **2** (without blades), water feed inlet point **1**, radial fluid dispersion via the central column and out through the disks to nozzles **12** mounted at the periphery of each of the ten disks, single independent fan **9** with blades **4** supplying refresh air to the ten disks, spray mist **5** from nozzles, air inlets **7**, disks cowling **3**, depiction of the airflow path through the system beginning with air inlets **7** and finishing with air out **8**.

[0099] FIG. **9** is an example of a dual-stage method and system which could utilize two of any of the evaporation stages described in FIGS. **1**-**8**. FIG. **9** diagrammatically depicts the optional two-stage evaporator and two-stage heat exchanger (HE **1** and HE **2**) arrangement that can create higher temperature differences than single stage evaporator systems, in addition to not humidifying interior air.

[0100] The two-stage method as shown in FIG. **9** works as follows. Expelled inside air **30** enters the first evaporation stage **32**, lowering the temperature and the cooled moist air enters a first separated flow air-to-air heat exchanger **34**. Fresh dry air **36** from the outside also enters the air-to-air heat exchanger **34** and flows contra-flow but both air streams do not actually mix; they are separated. Moist air from this stage **34** is expelled **38** outside and the cooled dry air from the first heat exchange stage then splits into two flows; the first **40** being to the 2nd evaporation stage **42** and the second **44** being the 2nd stage air-to-air heat exchanger **46**. The evaporation stage split is therefore pre-cooled dry air to the 2nd stage evaporation stage, allowing lower temperatures to be reached as previously mentioned. The cool, moist air **48** from the 2nd evaporation stage then flows to the 2nd stage air-to-air heat exchanger **46**, further cooling the already cooled dry air which then flows to the inside. The 2nd stage cooled moist air **50** then flows back to the first stage air-to-air heat exchanger **34** to further assist 1st stage cooling before being expelled outside. Fresh, dry, cooled air **52** flows to the inside of the building/room from the 2nd stage heat exchanger **46**.

[0101] FIG. **10** shows an arrangement of the inlet vanes **60** angled with respect to the radial direction R from the central hub **11** of the fan(s). These inlet vanes direct air in an opposite direction to the anti-clockwise rotation of the fan(s), thereby helping to increase velocity differential between the rotating nozzles and the airflow.

[0102] Nozzles can be on the leading edge of blades can be used; however, it has been found beneficial to provide the nozzles at the trailing edges of the blades or downstream of the blades relative to the direction of fan rotation.

[0103] Various modifications may be made in details of design and construction without departing from the scope or ambit of the present invention.

1. An evaporation system including at least one fan operatively connected to drive means to effect fan rotation, at least one flow path to supply the liquid to at least one nozzle on the at least one fan, the at least one nozzle spraying the liquid by centrifugal pressurisation when the at least one fan is rotating, and velocity differential between the rotating nozzle(s) and airflow created by the at least one fan providing evaporation of the sprayed liquid.

2. The system of claim **1**, wherein the at least one fan includes a vane axial fan.

3. The system of claim **1**, wherein the nozzles are provided on blades of the at least one fan.

4. The system of claim **3**, wherein at least one of the nozzles is located at or adjacent a respective fan blade tip and/or on the fan blades in an outer half of a radius from a rotation axis of the fan(s) to an outer peripheral edge of the fan(s).

5. The system according to of claim **1**, including air inlet vanes to direct refresh/incoming air over respective outlets of the nozzles.

6. The system of claim **5**, the inlet vanes disposed circumferentially with respect to the fan(s).

7. The system of claim **1**, wherein the at least one fan includes a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

8. The system of claim **5**, wherein at least some of the inlet vanes are angled away from a radial direction from a central axis of the fan(s) to direct air flow in a direction contra to a rotation direction of the fan(s).

9. The system according to of claim **1**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

10. The system according to of claim **1**, including a liquid supply means entering a hub of the at least one fan from a front, non driven side of the fan(s).

11. The system of claim **1**, including a liquid supply means entering a hub of the at least one fan from a rear, driven side, via a flow path inside a shaft or spindle.

12. The system of claim **11**, including liquid supply means entering via a hollow motor shaft to supply the liquid to fluid dispersal holes to a fan hub fluid dispersal chamber, distributing out through radial fluid dispersion conduits within the fan blades and then out through the nozzles.

13. A method of evaporation utilizing pressurized liquid flow through nozzles on a fan, the method including:

a) rotating a fan;
b) providing liquid under pressure to one or more of the nozzles on the fan;
c) discharging the liquid from the nozzles as a mist; and
d) evaporating the mist via a difference between nozzle velocity arising through rotation of the fan and air velocity created by the fan.

14. The method of claim **13**, including:

a) rotating a multi bladed fan;
b) providing a conduit along or through one or more of the fan blades to one or more nozzles on one or more of the fan blades to supply liquid to the nozzle(s);
c) centrifugally pressurizing the liquid supplied to the nozzle(s) by rotation of the fan;
d) spraying the liquid as a mist from the nozzle(s) by the centrifugal action and velocity of the nozzle(s) relative to airflow created by the fan.

15. The method of claim **14**, including distributing the liquid from a central hub of a respective fan through flow paths on or inside the fan blades to the nozzles.

16. The method according to claim **13**, including introducing air to the at least one fan via inlet vanes disposed circumferentially around the at least one fan.

17. The method of claim **16**, including guiding incoming airflow to the fan(s) in a direction contra to a direction of rotation of the fan(s).

18. The system of claim **2**, wherein the nozzles are provided on blades of the at least one fan.

19. The system of claim **2**, including air inlet vanes to direct refresh/incoming air over respective outlets of the nozzles.

20. The system of claim **3**, including air inlet vanes to direct refresh/incoming air over respective outlets of the nozzles.

21. The system of claim **4**, including air inlet vanes to direct refresh/incoming air over respective outlets of the nozzles.

22. The system of claim **2**, wherein the at least one fan including a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

23. The system of claim **3**, wherein the at least one fan including a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

24. The system of claim **4**, wherein the at least one fan including a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

25. The system of claim **5**, wherein the at least one fan including a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

26. The system of claim **6**, wherein the at least one fan including a central hub or disc supporting at least one of said nozzles to emit a mist out from the edge of the hub or disc when the at least one fan rotates.

27. The system of claim **2**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

28. The system of claim **3**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

29. The system of claim **4**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

30. The system of claim **5**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

31. The system of claim **6**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

32. The system of claim **7**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

33. The system of claim **8**, including flow paths on or inside the fan blades to distribute the liquid to the nozzles.

34. The system of claim **2**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

35. The system of claim **3**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

36. The system of claim **4**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

37. The system of claim **5**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

38. The system of claim **6**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

39. The system of claim **7** including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

40. The system of claim **8**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

41. The system of claim **9**, including a liquid supply means entering a hub of the at least one fan from a front, non-driven side of the fan(s).

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