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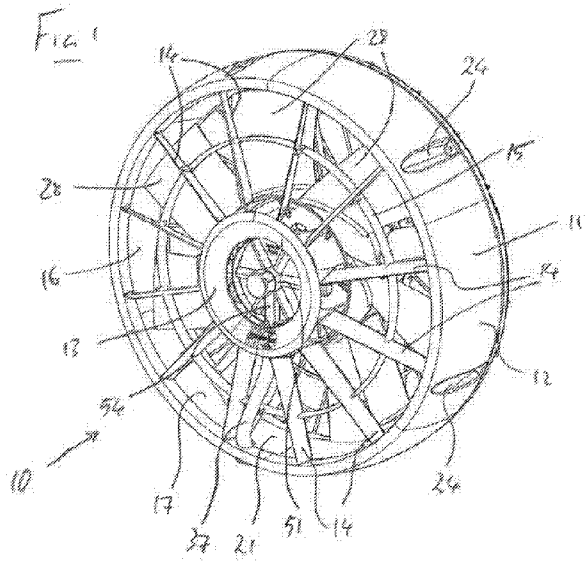

(57) Abstract: A fan assembly (10) including a plurality of fan blades (28) connected to a rotatable central fan hub (29) and extending radially outwardly from the fan hub (29) and being spaced equidistantly about the fan hub (29). An annular shroud (16) is provided within which the fan blades (28) rotate, whereby the tips of the blades (28) are in close facing relationship with a facing surface of the shroud (16). A plurality of radial spokes (20) extend from the shroud (16) to a fixed central shroud hub (22) which is coaxial with the fan hub (29). An air intake guard (33) is provided at the rear of the fan assembly (10) and includes a plurality of spaced apart radial spokes (34). A stator (11) is provided at the front of the fan assembly (10) and includes an annular ring (12) which is connected to the shroud (16) and a plurality of radial spokes (14) extend from the ring (12) to a fixed central stator hub (13) which is coaxial with the fan hub (29). A liquid delivery arrangement is provided that is connectable to a source of liquid, the liquid delivery arrangement including a plurality of discharge outlets (52) positioned to discharge liquid into the path of the fan blades (28) from adjacent the fan hub (29).

WO 2017/015708 A1

FAN ASSEMBLY

Technical Field

[0001] The present invention relates to a fan assembly and has been developed principally for the agricultural spraying industry, whereby the fan provides the motive energy for spraying liquid fertilisers, fungicides, pesticides, and the like onto agricultural crops. However, the fan assembly could have other applications given that its principal advantages over prior art fans are in terms of lightness, fan efficiency, ability to disperse aerosols and compactness.

Background of Invention

[0002] References herein to prior art are not to be taken as an admission that that prior art was known or that the prior art information was part of the common general knowledge as at the priority date of any of the claims.

[0003] The present invention has been developed in order to improve the efficiency involved in spraying liquids onto agricultural crops. In particular, the inventor has attempted to improve the extent to which spray penetrates beyond the external periphery or external foliage of a crop and into the interior of the crop. Penetration of spray into the interior of a crop can be quite difficult with certain crops, for example citrus crops and certain nut tree crops, as well as some tropical fruit crops. For instance, in the case of certain citrus crops these have quite stiff branches and the leaves of the foliage are difficult to displace, so that the external foliage tends to present a barrier to the internal foliage. This creates real problems for the spraying of citrus trees, given that where the exterior foliage of a tree is sprayed but not the interior foliage, infestation of the entire tree can still occur from the inside out.

[0004] The inventor has therefore sought to develop a fan that can more reliably apply sprays to agricultural crops that reach both the interior of the crop as well as the exterior.

[0005] Moreover, the inventor has sought to provide a fan that can provide the above benefit but at a rate of spray that is consistent with current spraying

equipment. That is, the speed at which spray is applied to crops is generally measured in terms of the speed at which the sprayer can be driven along the rows of crop. Typically the speed at which sprayers are driven along a row is between 3kph and 7kph, with 7kph being an upper maximum speed. Spraying personnel generally aim to spray between 5kph and 7kph. The upper maximum speed limit is often a function of the ground over which the spraying equipment moves, whereby the ground surface is often rough or uneven and prevents a tractor or truck or the like from travelling faster than that speed. The upper maximum speed limit can nevertheless be influenced by other factors such as the volume and density of spray to be deposited on a crop. In particular, where crops such as citrus crops are being sprayed, often the spray equipment is moved at a slower rate to increase the likelihood of spray penetration into the interior of the crop. This clearly slows down the rate at which the target area can be sprayed and typically increases the amount of spray that is used and wasted. That is, because it is generally quite easy to spray the external foliage of a crop, moving the spraying apparatus more slowly tends to deposit more spray on the external foliage than is required and this either drips from the foliage onto the ground, or is retained on the foliage, but is in excess of what is required.

[0006] In developing the present invention, the inventor has developed a fan assembly that not only achieves exceptional results in terms of spraying efficiency when used as a fan for spraying agricultural crops, but the inventor has also created a fan which is lightweight compared to comparable fans used on other spray equipment, is easy to assemble from component parts and which has a greater efficiency in terms of output compared to comparable fans and has higher rates of penetration into crop foliage. While these latter outcomes were not necessarily intended or expected at the outset of the development, they are very pleasing and result in additional savings when used in spraying equipment in terms of reduced weight of spraying equipment and reduced energy needed to drive the fans.

Summary of Invention

[0007] In a very broad form, a fan assembly according to the invention includes a plurality of fan blades that are connected to a rotatable central fan hub and

which extend radially outwardly from the fan hub and are spaced equidistantly about the fan hub. The fan assembly also includes an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with the facing annular surface of the shroud.

[0008] By the requirement that the blade tips are in close facing relationship with the facing annular surface of the shroud, the preference is that the blade tips are within 2 to 10mm of the facing annular surface of the shroud, or more preferably within 2 to 5mm of the facing annular surface of the shroud. There will naturally be some movement between the blade tips and the facing annular surface of the shroud during use of the fan assembly when the blades are rotating (such as when the fan assembly is being moved along an uneven ground surface between adjacent rows of crops) so that the spacing between the blade tips and the facing annular surface of the shroud can vary but it is an average spacing that is meant when the millimetre distances are given above. There will also naturally be some tolerance variations in the fan assembly so that even when the fan assembly is stationary, the spacing between the blade tips and the facing annular surface of the shroud may vary about the internal circumference of the annular shroud. Again however, it is an average spacing that is meant when the millimetre distances are given above.

[0009] The fan assembly further includes a liquid delivery arrangement for delivering liquid generally centrally of the fan assembly into the path of the fan blades, or into the path of airflow generated by rotation of the fan blades. By this arrangement, liquid which is delivered in this manner will be picked up by airflow delivered by the fan blades for distribution onto the foliage of an agricultural crop being sprayed. This central form of liquid delivery is unique in relation to agricultural sprayers, in which typically, the liquid is delivered at the periphery of the annular shroud, or adjacent to the blade tips. That prior art arrangement has disadvantages in that it requires a metal (usually stainless steel) tube or conduit to be formed in a ring at the periphery of the annular shroud and requires the ring to include openings for the connection of nozzles. The ring, nozzles and fittings between the ring and the shroud and between the ring and the nozzles, must all be very robust, because of the propensity or likelihood of the ring and nozzles to

be damaged by branches and foliage in the normal course of the use of the spraying fan. That is, fans in general tend to be bumped or knocked in their ordinary use during a spraying operation and placing the ring and nozzle arrangement at the periphery of the shroud requires the arrangement to be sufficiently robust to survive those impact loads. This means that the prior art arrangements are heavy and quite expensive, and are difficult to replace if damaged, because of the secure mounting arrangements employed to keep them in place.

[0010] In contrast, the present invention proposes to deliver liquid generally centrally of the fan assembly, which places the delivery assembly in a very protected position. The assembly therefore can be less robust and less complex and can be mounted in a manner which is more easily replaced if required. The inventor believes that the central mounting that has been developed can be much cheaper than the prior art mounting discussed above, thereby contributing to a reduced cost for fan assemblies according to the invention. Another advantage of the central liquid delivery is that the liquid is immediately entrained in the air stream, ensuring good and uniform dispersal of the liquid, rather than attempting to enter the air stream from the periphery of the fan where not all of the liquid is entrained for good dispersal.

[0011] In a more specific form of the invention in which central liquid delivery is provided, a fan assembly according to the invention can include:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub;

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is coaxial with the fan hub;

an air intake guard at the rear of the fan assembly and including a plurality of spaced apart radial spokes;

a stator at the front of the fan assembly, the stator including an annular ring which is connected to the shroud and a plurality of radial spokes extending from the ring to a fixed central stator hub which is coaxial with the fan hub;

a liquid delivery arrangement that is connectable to a source of liquid; and

the liquid delivery arrangement including a plurality of outlets positioned to discharge liquid into the path of air delivery from the fan blades from adjacent to the fan hub.

[0012] In an alternative form of the invention described above, the air intake guard and the stator and their associated spokes and other components can be omitted.

[0013] In relation to the front and rear annular edges of the shroud, these are spaced apart axially or in the direction of airflow through the fan. The edges can be parallel.

[0014] The advantages of discharging liquid centrally of the fan assembly have been discussed above. In the above form of the invention, discharge is defined as being adjacent the fan hub, which is generally centrally of the fan assembly. Liquid discharge could be radially inboard of the fan hub, or outboard of the hub and still be within the scope of the requirement for generally central discharge.

[0015] Any number of discharge outlets can be provided. The inventor has tested versions of the invention that include eight outlets and eleven outlets. However, it would be equally acceptable for a fan assembly according to the invention to have a minimum of two discharge outlets, and thereafter three, four, six, eight, ten or twelve outlets, or odd numbers of outlets between those. As the fan assembly grows in size, the number of outlets can be increased if desirable.

[0016] The discharge outlets could be positioned upwind of the fan blades and inject liquid into the path of the fan blades, or into the path of airflow generated by

rotation of the fan blades, for distribution. However, the preference is that the liquid discharge occurs downwind of the fan blades, and the preference is that the discharge occurs adjacent to the root or roots of the blades. In the blade assembly that will be described later herein in relation to the accompanying drawings, it will be shown that the discharge outlets are adjacent to the blade roots, but that the point of discharge is actually radially outside the blade roots. The discharge outlets themselves are therefore within the path of airflow generated by rotation of the fan blades, but not within the high wind velocity section of the airflow. This again differs from prior art arrangements where the discharge outlets or nozzles are positioned at the periphery of the fan assembly, or adjacent the blade tips, whereby discharge of liquid in those arrangements is straight into the highest air velocity produced by the fan blades. The method of liquid discharge of the invention ensures that the liquid droplets that are discharged from the discharge outlets are fully swept up into the air stream produced by the fan blades for efficient dispersal as a mist or aerosol and to thus reach their intended target (the foliage and fruit in crop spraying). This differs from prior art arrangements that have the discharge outlets positioned at the periphery of the annular shroud whereby some of droplets that are discharged are blown peripherally outwards, thereby resulting in droplets not effectively reaching the foliage, and leading to environmental losses and higher costs of spraying.

[0017] The discharge outlets of the liquid delivery arrangement can take any suitable form and can be formed as nozzle discharge outlets. The nozzles can be adjustable so that the liquid which is discharged through them can be coarse or fine droplets, and the nozzles can be removable for replacement, for example, if they are damaged or if a nozzle with different characteristics is required.

[0018] While the liquid delivery arrangement can take any suitable form, in one form, a single liquid inlet is provided which feeds a plurality of liquid delivery conduits that extend to or form the discharge outlets. In one form, the single liquid inlet can feed a central delivery port to which each of the liquid delivery conduits connects to or opens into and the liquid delivery conduits can then extend to a plurality of nozzle outlets. The nozzle outlets can be formed at the opposite end of the liquid delivery conduits to the central delivery port. The nozzle outlets can be

formed as nozzles or they can be arranged for the attachment of nozzles. In a very simple form, the nozzle outlets of the liquid delivery conduits are the open ends of the liquid delivery conduits without any additional formation.

[0019] The liquid delivery conduits can be tubes, such as rigid or flexible metal or polymer tubes. Alternatively, the conduits can be formed in a manifold or block that can be machined or moulded, preferably injection moulded. This latter form of manifold can be produced inexpensively and highly accurately and be lightweight but robust. An injection moulded manifold can also include metal inserts where required, such as for the attachment of nozzles. Alternatively, if the moulding material is suitable, the nozzles can be threaded directly into the conduit outlets of the manifold to tap their own thread, or a thread can be formed as part of the moulding process. An injection moulded manifold (or a machined manifold) can be generally solid apart from the liquid delivery conduits and can be positioned either downstream of the fan hub, downstream of the stator hub, or between the fan and the stator hubs. The manifold can be fixed in any suitable manner such as to the stator by bolting.

[0020] A fan assembly according to the invention can be provided with an intake guard of unique conical construction. The guard is provided for safety to prevent injury to personnel that use the fan assembly, but it can also be provided to prevent or limit the entry of debris into the fan assembly that is drawn into the fan as the fan draws air. It is to be noted that a fan assembly according to the invention is intended to be high volume and so the volume of air being drawn into the fan will also be high and there will be a potential for the fan to draw debris along with air, particularly if the fan assembly is positioned close to the ground. The intake guard can extend from the periphery of the fan assembly, such as from the shroud or stator, to a central portion of the fan assembly and according to some forms of the present invention, is formed as a cone that inclines in the direction of airflow through the fan from a high point centrally of the fan assembly to a low point at the periphery of the fan. That is, with the fan facing downwardly, the intake guard would also incline downwardly from the centre region of the fan to the periphery of the fan.

[0021] The above form of intake guard has been developed by the inventor for the fan assembly when used for spraying agricultural crops, because such fans are often subject to a significant amount of leaf debris being sucked into the fan upwind of the fan. That is, with the fan being operated, a significant amount of air is sucked into the fan and this air can carry debris, including leaf debris with it. The intake guard therefore can be arranged to prevent the entry of a significant proportion of that debris, and the conical nature of the intake guard means that the debris can slide down the conical surface under the influence of the air intake, and can be discharged from the intake guard at the periphery of the guard, or at the periphery of the shroud. By discharged, it is meant that the leaf debris will travel down the conical surface of the intake guard under the influence of the pneumatic load applied to the debris by the rotating fan blades, but once the debris reaches the periphery of the guard or the shroud, the pneumatic load will drop and the debris can fall from the fan assembly having not passed into the fan assembly, Advantageously, this can minimise the amount of debris that enters the fan and which can potentially clog rotating components of the fan, or which can be discharged through the fan and into the crop being sprayed. Further, manual cleaning of the air intake can be reduced or eliminated.

[0022] The air intake guard as described above can be employed with fan assemblies according to the invention as discussed above, for example a fan assembly that includes fan blades and a shroud, or in can be combined with the form of fan assembly discussed above that includes a liquid delivery arrangement. As will be evident from the discussion of the drawings which follows, that combination is embodied in the fan assembly illustrated in the drawings.

[0023] In a more specific form of this version of the invention, a fan assembly is provided which includes:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fan blades being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the

facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is coaxial with the fan hub,

an air intake guard at the rear of the fan assembly and including a plurality of spaced apart radial spokes, the spokes being formed in a conical array that inclines from a generally central part of the fan assembly to a peripheral part of the fan assembly.

[0024] A fan assembly of the above kind can include characteristics of the fan assemblies disclosed earlier herein, and for example, can include a stator at the front of the fan assembly. In some forms of the invention, the stator can include an annular ring which is connected to the shroud and a plurality of radial spokes extending from the ring to a fixed central stator hub which is coaxial with the fan hub. The radial spokes can be provided just for structural purposes and also for directional air flow purposes as will be described later herein.

[0025] The radial spokes of the air intake guard can be wire spokes (thin spokes) and can be spaced apart sufficiently that air being induced into the fan assembly is not overly restricted by the intake guard. For support, the radial spokes can be connected at either end to annular rings at each of the central part of the fan assembly and at the peripheral part of the fan assembly. The rings can be interrupted as required for connecting the intake guard to the fan assembly. A further annular ring can be provided between the annular rings discussed above for connection to the spokes for support and rigidity purposes.

[0026] In developing the fan assembly of this specification, the inventor aimed to improve the penetration of spray into the interior of crops being sprayed. In the discussion of prior art above, it was noted that citrus and some nut and tropical fruit trees in particular are difficult to spray completely given the rigidity of the braches of such trees and the difficulty in creating openings in the foliage for spray to penetrate to the interior of the tree. The inventor therefore sought to develop a fan assembly in which the airflow emitted from the assembly was emitted in a swirling motion, in order cause a shaking or flapping motion of the foliage and branches of a target tree, with the intent that this would cause openings to be

formed in the external parts of the foliage for spray to enter into the interior foliage. Accordingly, the inventor developed a fan assembly that includes:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is upwind and coaxial with the fan hub,

the radial spokes being formed as fixed vanes which are relatively thin and which have a depth in the axial direction of the fan assembly, the vanes having an angle of attack greater than zero to the direction of axial flow through the shroud in order to promote directional change of airflow through the shroud and prior to the fan blades.

[0027] The inventor has discovered that a fan assembly of the above kind can assist to form an air output from the fan assembly that swirls. The air output can have a number of swirling components rather than single swirling output. As would be apparent from the discussion above, that swirling motion can assist to displace the leaves and branches of crops being sprayed so that the interior of the crop is accessible for coverage. Testing by the inventor of the fan assemblies according to the invention has shown that swirling motion is effective for the displacement discussed above and testing has shown that spray penetration into the interior of citrus trees in particular, is achieved by fan assemblies according to the present invention in which the radial spokes of the fan assembly are formed as vanes with an angle of attack which is greater than zero. The preference is that the angle of attack of each of the fixed vanes is the same, although it could be that in some embodiments, the angle of attack can vary.

[0028] In forms of the invention which include a stator, the radial spokes of the stator can also be formed as fixed vanes which are relatively thin and which have

a depth in the axial direction of the fan assembly. The vanes can have an angle of attack which is greater than zero to the direction of axial flow through the stator again, in order to promote directional change of airflow through the stator and downwind of the fan blades. Again, the preference is that the angle of attack of each of the vanes is the same, although it could be that in some embodiments, the angle of attack can vary.

[0029] In alternative forms of the invention which include a shroud and a stator and in which both include radial spokes, the radial spokes of both the stator and the shroud can be formed as fixed vanes which are relatively thin and which have a depth in the axial direction of the fan assembly, but only the vanes of the stator have an angle of attack greater than zero to the direction of axial flow through the stator in order to promote directional change of airflow through the stator and downwind of the fan blades.

[0030] In a preferred fan assembly according to the invention, each of the shroud and the stator includes the fixed vanes as described above that have an angle of attack greater than zero to the direction of axial airflow through the respective shroud and stator. Where each of the shroud and stator include angled vanes, the swirling motion of air discharged through the fan assembly is maximised. The vanes of the shroud and stator can each be angled or have an angle of attack in the same direction or they can be angled in opposite directions. Also, where the angle of attack between the vanes of the shroud and stator are opposite, the respective angles of attack can be of the same value (but in opposite direction) or can be of different value.

[0031] The radial spokes of the shroud and a stator can be straight or can have a twist from root to tip. The twist can be variable or constant. In this form of the invention, the angle of attack of the spokes will vary from root to tip. Accordingly, the where ranges are given for the angle of attack these can provide the minimum angle at the root up to the maximum angle at the tip. The selected angle can be dependent on the amount of swirl required and the velocity of air being produced. In one form of the invention, the angle of attack of the vanes of the stator at the root of the vanes can be 17.6 degrees, and at the vane tips can be 22.4 degrees. In one form of the invention, the angle of attack of the vanes of

the shroud at the root of the vanes can be 27.4 degrees, and at the vane tips can be 29.2 degrees. These are examples only and the angle of attack can vary as required.

[0032] It is to be noted that where the radial spokes of the shroud and/or the stator are formed as fixed vanes of the kind described above, the vanes can be formed to have an aerofoil shape.

[0033] Moreover, the shroud can be formed in any of the embodiments discussed herein as having a duct profile, so that it promotes air intake through the shroud. A duct profile is a profile in which the interior surface of the duct is curved from a wider opening to a smaller opening (forming a venturi), while the outlet of the duct downwind of the opening can continue this curvature, or can be relatively straight.

[0034] In any of the different embodiments of a fan assembly according to the invention discussed above, the fan blades can be angled from the fan hub forward or in the direction of air flow through the fan assembly as this can facilitate the use of a conical air intake guard as described before. In this arrangement, the annular shroud can be displaced upwind of the shroud hub, with the radial spokes of the shroud extending at an angle between the shroud and the shroud hub. Likewise, the fan hub can be positioned coaxial with the shroud hub, with the fans being angled forwardly in the upwind direction to match the forward mounting of the shroud spokes and the conical form of the air intake.

Brief Description of Drawings

[0035] In order that the invention may be more fully understood, some embodiments will now be described with reference to the figures in which:

[0036] Figure 1 is a perspective view of a fan assembly according to one embodiment of the invention.

[0037] Figure 2 is an exploded rear side view of the fan assembly of Figure 1.

[0038] Figure 3 is an exploded front side view of the fan assembly of Figure 1.

[0039] Figure 4 is a front view of the fan assembly of Figure 1.

[0040] Figure 5 is a side view of the fan assembly of Figure 1.

Detailed Description

[0041] Figure 1 is a perspective front view of a fan assembly according to an embodiment of the invention. The fan assembly 10 includes a stator 11 which includes a peripheral annular ring 12, a central stator hub 13 and a plurality of radial spokes 14 that extend between an inside surface of the ring 12 and the hub 13. A further annular ring 15 extends between the ring 12 and hub 13 and assists to retain the spokes 14 against movement and flexing.

[0042] The ring 12 of the stator 11 is connected to an annular shroud 17 only the inside surface of which is visible in Figure 1. This shroud is better illustrated in the exploded view of Figure 2 and reference will also be made to that figure hereinafter.

[0043] The shroud 17 includes a front annular edge 18 and a rear annual edge 19 whereby reference to front and rear is a directional reference relative to the direction of airflow through the fan assembly. The front edge extends from a generally cylindrical section while the rear edge extends from a section that is formed as a duct as defined earlier herein.

[0044] The shroud 17 also includes a plurality of radial spokes 20 and in the illustrated arrangement, five spokes 20 are employed, although not all are visible in either Figure 1 or 2. The spokes 20 extend from the inside surface 21 of the shroud 17, to a central shroud hub 22. The hub 22 is annular and coaxial with the shroud ring 17 and with the hub 13 of the stator 11.

[0045] The outer surface of the stator ring 12 includes a plurality of equidistantly spaced recesses 24 which are provided to accommodate fasteners which fasten the stator 11 to the shroud 16. The further exploded view of Figure 3 shows the openings 25 formed in the annular edge 19 of the shroud 16 that receive the fasteners that are accommodate in the recesses 24.

[0046] Disposed within the ring 17 of the shroud 16 is a fan 27 which comprises a plurality of fan blades 28 mounted to a rotatable fan hub 29. Seven blades 28 are included in the illustrated arrangement.

[0047] An endcap 30 mounts to the edge 31 of the shroud hub 22 and the endcap 30 forms a connection point for the air intake guard 33. The air intake guard includes a plurality of spaced apart radial spokes 34 (see Figure 5) that extend between an inner annular ring 35 and an outer annular ring 36. The annular ring 36 is interrupted at the gap G (see Figure 3) for the passage of a liquid delivery hose 37, that will be discussed later herein.

[0048] A motor 40 includes a rotatable drive spindle 41 that engages through a spline connection with a boss 42 of the fan 27. The motor 40 can be electrically or hydraulically driven. In this respect, the preferred manufacturing form for the fan 27 is to injection mould the fan about a metallic boss, which includes a groove for receipt of the spline formed on the spindle 41. The motor 40 includes a flange 43 which includes openings for receipt of fasteners to connect it to the radial section 44 of the shroud hub 22. The spindle 41 extends through the opening 45 of the section 44 and into engagement with the boss 42 of the fan 27. Those fasteners also extend into openings formed in return tabs 46 which form part of the mounting arrangement to mount a fan assembly 10 to a post 47. The mounting arrangement includes a pair of side plates 48 which are identical and which can be clamped by bolts 49 onto the post 47 which can be part of a spraying apparatus.

[0049] The fan assembly 10 further includes a liquid delivery arrangement, which in Figures 1 to 3 comprises a delivery hose 37 that extends to a supply of liquid, generally pressurised liquid, and which feeds a plurality of liquid delivery conduits 50 through a central delivery port 51. Each of the conduits 50 opens into the port 51 and extends to a plurality of nozzle outlets 52. Figures 3 and 4 in particular show a nozzle 53 applied to one of the nozzle outlets 52, but the other nozzle outlets are shown without an actual nozzle fitted thereto. This shows that nozzles 53 can be removed from the nozzle outlets 52 and replaced if damaged, or replaced if a different style of nozzle, having a different spray pattern for example, is to be used.

[0050] Figures 4 and 5 are front and side views of the fan assembly as shown in Figure 1.

[0051] It will evident from the figures that the nozzle 53 forms one outlet through which liquid is discharged into the flow path of the fan blades 28. As shown in Figure 4, the nozzle 53 is positioned adjacent to and downwind of the root of the fan blades 28 where the fan blades connect to the hub 29. The spray from the nozzle therefore sprays liquid, in droplet form, into the path of the fan blades from a position generally centrally of the fan assembly. In prior art arrangements, the nozzles would be positioned adjacent to the outer annular periphery of the stator 11 or the shroud 16, such as adjacent the annular edge 18 of the shroud 16. It will be appreciated that in that construction, a tube, typically a stainless steel tube, would need to have a diameter approximately equal to the diameter of the edge 18 and include fittings for attachment of suitable nozzles. As indicated before, by positioning the nozzles at the periphery of the fan assembly, they are more likely to be damaged by interaction with the crops being sprayed, or by interaction with equipment, such as other farming equipment.

[0052] The conduits 50 are fed through an inlet feeder 54 (see Figures 1 and 4), that feeds to the port 51 and through which delivery is made to the conduits 50. Each of the conduits 50 and the feeder 54 could alternatively be formed in a solid block, manifold or body which is injection moulded or machined. In fact, this is preferred as a solid block, manifold or body can be can be produced inexpensively and highly accurately and be lightweight but robust. An injection moulded block, manifold or body can also include metal inserts where required, for the attachment of nozzles. Alternatively, if the moulding material is suitable, the nozzles can be threaded directly into the conduit outlets of the block, manifold or body to tap their own thread, or a thread can be formed as part of the moulding process. An injection moulded block, manifold or body (or a machined block, manifold or body) can be generally solid apart from the liquid delivery conduits and can be positioned either downstream of the fan hub 29, downstream of the stator hub 13, or between the fan and the stator hubs. The block, manifold or body can be fixed in any suitable manner such as to the stator 11 by bolting.

[0053] The intake guard 33 is clearly shown in Figures 2 and 3, but Figure 5 most clearly shows the conical nature of the guard.

[0054] It can be seen from Figure 5 that the depth of the intake guard 33 is greatest at the inner annular ring 35, and inclines downwardly to the ring 36. This forms a conical guard or barrier against ingress of debris such as leaves and twigs etc, when the fan assembly is operating and debris is present. The debris tends to slide in a direction towards the outer annular ring 36 under the influence of the pneumatic load applied to the debris by the rotating fan blades 28, and by that mechanism, the debris is therefore removed from blocking the air intake to the fan 27. Once the debris reaches the periphery of the guard or the shroud, the pneumatic load will drop and the debris can fall from the fan assembly having not passed into the fan assembly. This is in contrast to prior art arrangements which tend to have a generally flat guard, so that debris that is sucked onto the guard remains on the guard until it is cleared manually.

[0055] Figures 2 and 3 clearly show the angle at of the radial spokes 20 of the shroud 16. The spokes 20 have an angle of attack greater than zero and are formed as vanes, which are relatively thin and which have a depth extending between the edge 31 of the hub 22 and the radial section 44 of the hub 22. The angle of the spokes 20 can be seen relative to a straight datum line D (see Figure 2). The spokes 20 as shown in the figures alter the direction of flow of air from upwind of the shroud to downwind of the shroud. Thus, air that is drawn past the spokes 20 tends to be redirected in the angular direction in which the spokes 20 are positioned, and therefore approaches the blades 28 already in a non-axial direction. As discussed earlier, this tends to promote a swirling motion in the air that is delivered from the fan assembly 10 giving the benefits as described above in relation to interior penetration of agricultural crops.

[0056] To assist the swirling motion which is promoted by the spokes 20, the spokes 14 of the stator 11 are also positioned to have an angle of attack greater than zero. This can readily be seen in Figures 1 and 4 and in those figures, while the spokes 14 have a reduced depth compared to the spokes 20, they nevertheless are angled and cause the air that is delivered through the stator 11 by the fan 27 to continue the swirling motion which has already been established.

The depth of the spokes 14 and 20 can be increased or decreased as required. The swirling motion which is created by the arrangement discussed above has been shown to improve the level of spray penetration into the interior of agricultural crops, in particular citrus crops.

[0057] With reference to Figure 5, it is evident that the fan assembly 10 is of much more compact construction than the prior art fans. Many prior art fans would have a depth which is approximately twice that of the fan assembly 10 and thus would be much heavier and more costly. This arises somewhat due to the overlying arrangement of the stator and the shroud. That is, they are not connected in series, but rather, the shroud nests within the stator. This also arises somewhat due to the liquid delivery arrangement that is described and which if very compact due to the position centrally of the fan assembly.

[0058] In addition, the inventor has designed the fan so that most of the parts can be formed from plastic and can be injection moulded. In this regard, each of the stator, the shroud, the fan and the liquid delivery arrangement can be injection moulded from plastic or resin material. This dramatically reduces the weight of the fan assembly when compared with prior art fans which are predominantly made from metal or which are rotational moulded.

[0059] In addition, injection moulding of the fan and shroud enables a very accurate mating arrangement between the tips of the fan blades 28 and the inside surface of the ring 17 of the shroud 16. While many prior art fans have a gap of between 10mm and 12mm between the fan tip and the facing shroud surface, the inventor has achieved a gap (an average gap as described above) in the region of 4mm to 5mm. This substantially increases the efficiency of the fan by reducing flow loses between the shroud and the blades. Accordingly, it is a feature of the invention that one or more of the fan, the shroud and the stator are injection moulded.

[0060] Throughout the description and claims of the specification, the word "comprise" and variations of the word, such as "comprising" and "comprises", is not intended to exclude other additives, components, integers or steps.

[0061] The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the present disclosure.

CLAIMS

1. A fan assembly, including:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is coaxial with the fan hub,

an air intake guard at the rear of the fan assembly and including a plurality of spaced apart radial spokes,

a stator at the front of the fan assembly, the stator including an annular ring which is connected to the shroud and a plurality of radial spokes extending from the ring to a fixed central stator hub which is coaxial with the fan hub,

a liquid delivery arrangement that is connectable to a source of liquid,

the liquid delivery arrangement including a plurality of discharge outlets positioned to discharge liquid into the path of the fan blades from adjacent the fan hub.

2. A fan assembly according to claim 1, the discharge outlets being positioned adjacent to and downstream of the root of the fan blades.

3. A fan assembly according to claim 2, the discharge outlets being spray nozzle discharge outlets.

4. A fan assembly according to claim 3, the liquid delivery arrangement including a plurality of liquid delivery conduits and the discharge nozzles being removably connected to outlets of the liquid delivery conduits.

5. A fan assembly according to any one of claims 1 to 3, the liquid delivery arrangement including a manifold positioned adjacent the fan hub, the manifold including an inlet for receipt of liquid and including a plurality of liquid delivery conduits in liquid communication with the inlet and which include the discharge outlets through which liquid is discharged.

6. A fan assembly according to claim 5, the manifold including a generally solid body through which the liquid delivery conduits are formed.

7. A fan assembly according to claim 6, discharge nozzles being removably connected the discharge outlets of the liquid delivery conduits.

8. A fan assembly according to any one of claims 5 to 7, the manifold being positioned between the fan hub and the stator hub.

9. A fan assembly, including:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is coaxial with the fan hub,

an air intake guard at the rear of the fan assembly and including a plurality of spaced apart radial spokes, the spokes being formed in a conical array that inclines from a generally central part of the fan assembly to a peripheral part of the fan assembly, the depth of the intake guard being greater at the central part of the fan assembly than at the peripheral part of the fan assembly.

10. A fan assembly according to claim 10, further including a stator at the front of the fan assembly, the stator including an annular ring which is connected

to the shroud and a plurality of radial spokes extending from the ring to a fixed central stator hub which is coaxial with the fan hub.

11. A fan assembly according to claim 9 or 10, the radial spokes of the intake guard being wire spokes.

12. A fan assembly according to any one of claims 9 to 11, the radial spokes being connected to annular rings at the central part of the fan assembly and at the peripheral part of the fan assembly.

13. A fan assembly, including:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is upwind and coaxial with the fan hub,

the radial spokes being formed as fixed vanes which are relatively thin and which have a depth in the axial direction of the fan assembly, the vanes having an angle of attack greater than zero to the direction of axial flow through the shroud in order to promote directional change of airflow through the shroud and prior to the fan blades.

14. A fan assembly, including:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate, whereby the blade tips are in close facing relationship with a facing annular surface of the shroud, the facing surface being positioned between front and rear

annular edges of the shroud, a plurality of radial spokes extending from the shroud to a fixed central shroud hub which is upwind and coaxial with the fan hub,

a stator at the front of the fan assembly, the stator including an annular ring which is connected to the shroud and a plurality of radial spokes extending from the ring to a fixed central stator hub which is coaxial with the fan hub,

the radial spokes being formed as fixed vanes which are relatively thin and which have a depth in the axial direction of the fan assembly, the vanes having an angle of attack greater than zero to the direction of axial flow through the stator in order to promote directional change of airflow through the stator and downwind of the fan blades.

15. A fan assembly, including:

a plurality of fan blades connected to a rotatable central fan hub and extending radially outwardly from the fan hub, the fans being spaced equidistantly about the fan hub,

an annular shroud within which the fan blades rotate,

a liquid delivery arrangement that is connectable to a source of liquid,

the liquid delivery arrangement including a plurality of outlets positioned to discharge liquid into the path of air delivery from the fan blades generally centrally of the fan assembly.

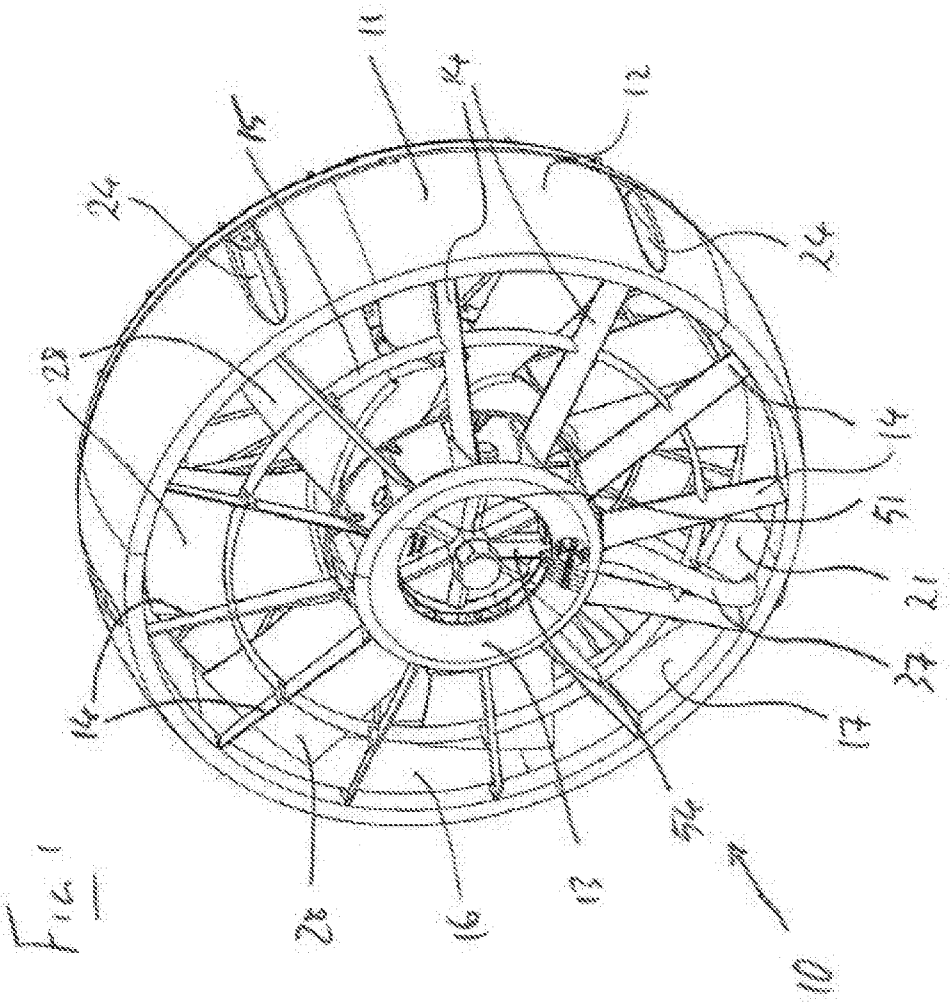

Fig. 1

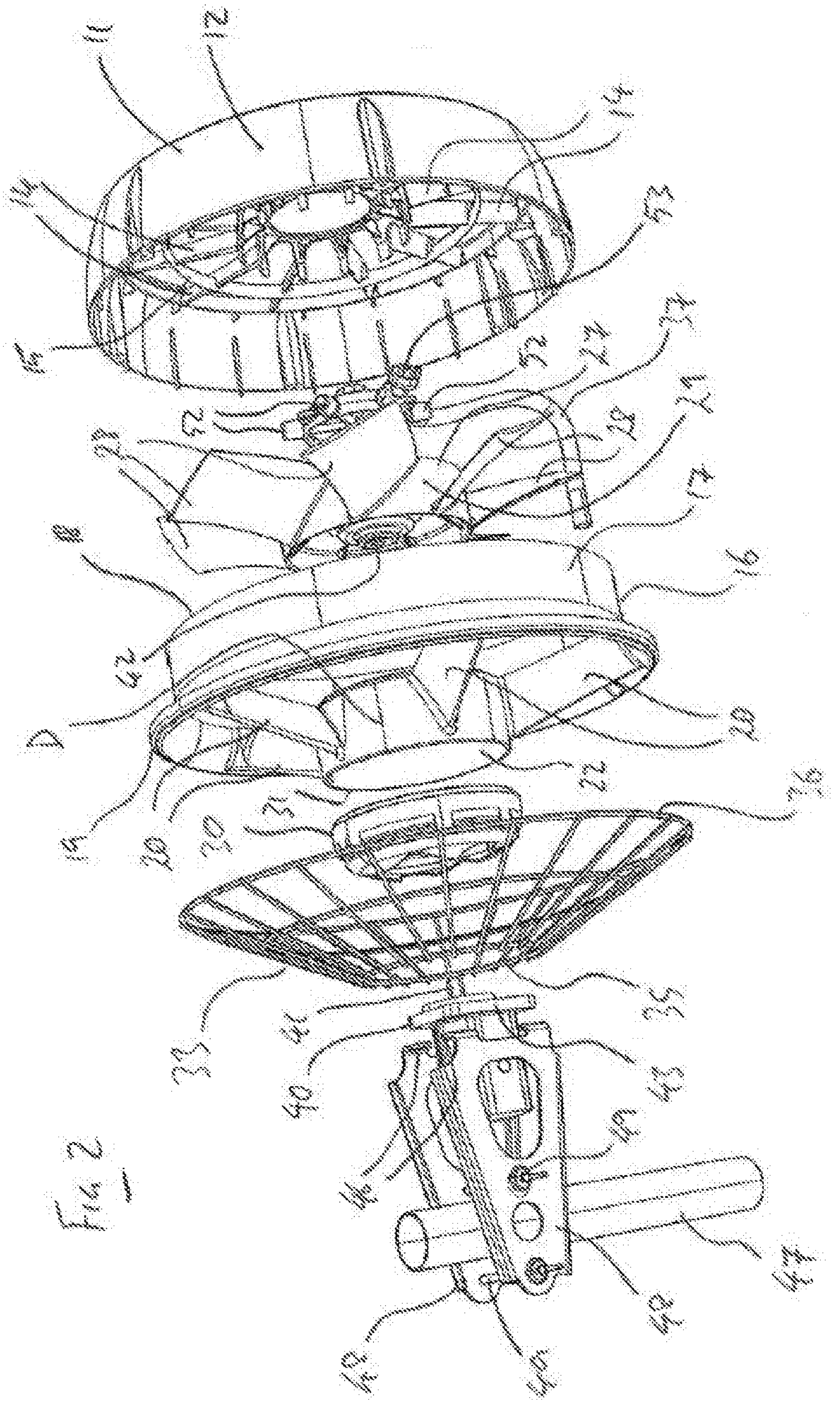

Fig 2

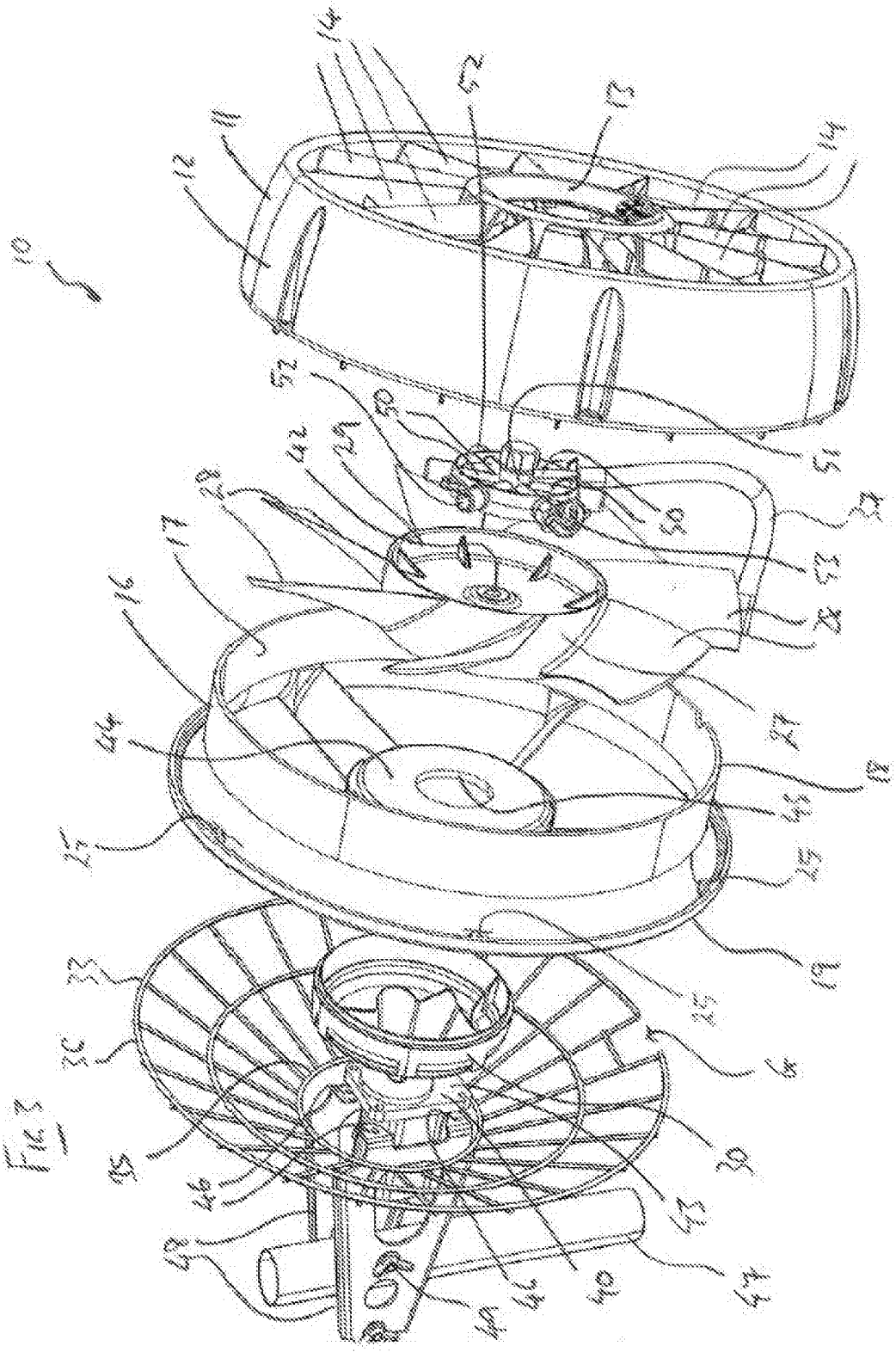
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Fig 3

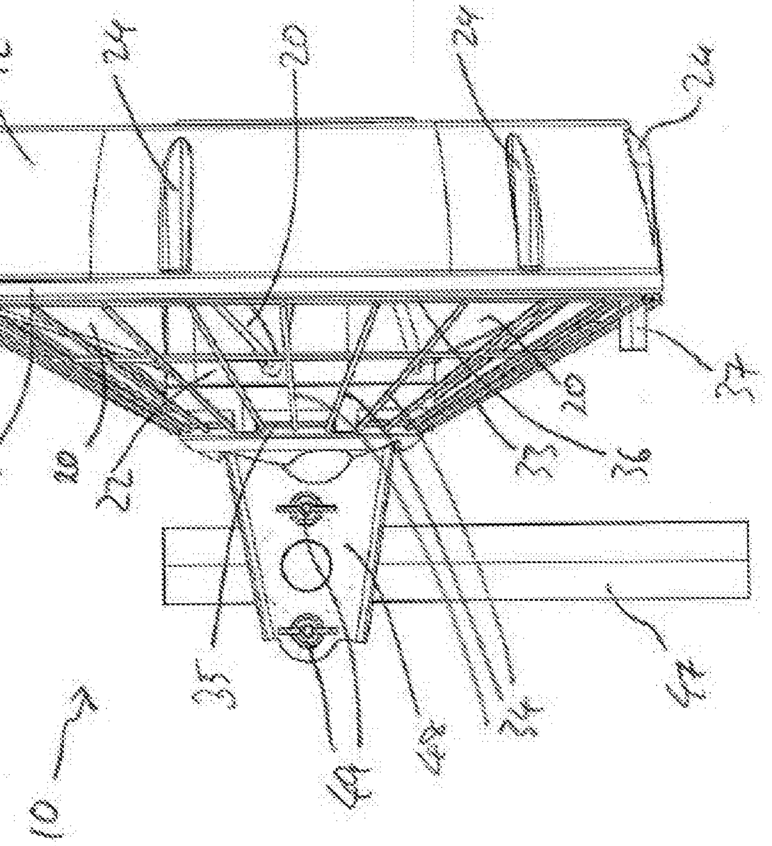

Fig 5

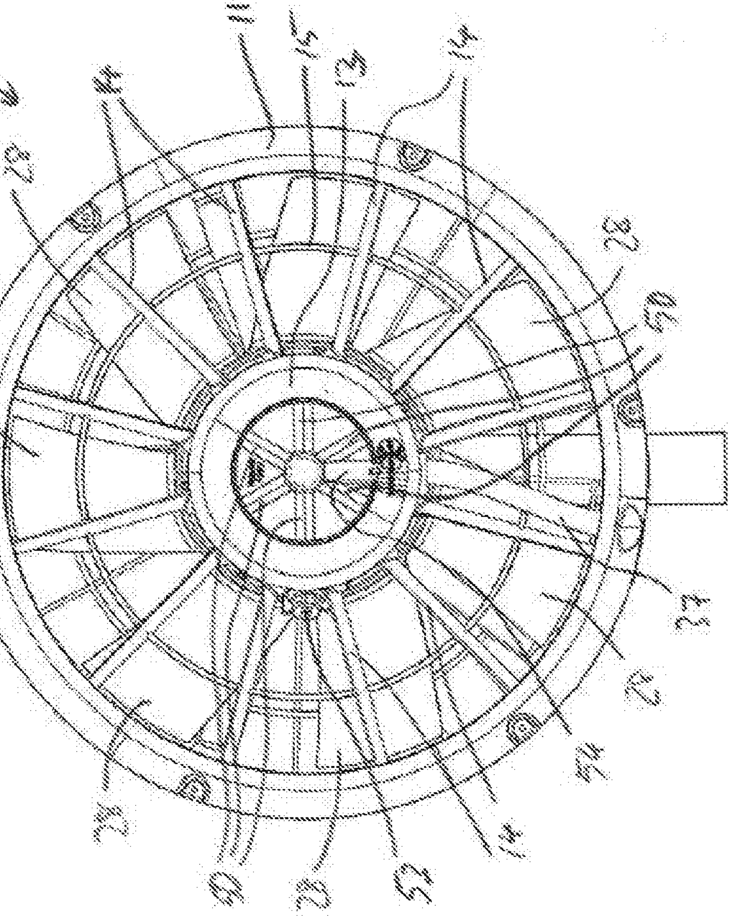

Fig 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2016/050663

A. CLASSIFICATION OF SUBJECT MATTER

A01M 7/00 (2006.01) A01C 15/04 (2006.01) B05B 3/02 (2006.01) F24F 6/12 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

EPODOC/WPIAP/TXTE; IPC/CPC Marks A01M7/0014, A01C23/047, A01C23/001, A01C15/04, B05B3/022, B05B3/105, B05B7/2416, A01M7, A01C23, A01C15, B05B3, B05B7, F04D19/002/low, F24F6 and Keywords: fan, blade, shroud, stator, guard, nozzle, cone, foliage and similar terms.

Google Patents/Espacenet/Auspat/Google/PAMS Nose/INTESS; IPC/CPC Marks A01M7, A01C15, A01C23, B05B3, B05B7, F24F6, A01M7/0014 and Keywords fan, blade, shroud, stator, grille, nozzle and similar terms; applicant/inventor names searched.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2016	30 August 2016
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Yew-Seng How AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832945

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2016/050663**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 1335896 A (VEB KOMBINAT LUFT UND KAELTETECHNIK) 31 October 1973 Figs 1-5; Page 1 Line 11 – Page 2 Line 57	1-15
X	US 3655130 A (PATRICK) 11 April 1972 Abstract; Figs 5-9; Col 7 Line 50 – Col 9 Line 68	1-15
X	US 3706417 A (PATRICK) 19 December 1972 Abstract; Figs 1-8; Col 1 Line 13 – Col 6 Line 9	1-15
X	US 6257502 B1 (HANISH et al) 10 July 2001 Abstract; Figs 1-11; Col 1 Line 10 – Col 6 Line 18	1-15
X	US 2013/0219933 A1 (HUBERT et al) 29 August 2013 Abstract; Figs 1-20; Paras 0001-0068	1-15
X	US 6086053 A (NATSCHKE et al) 11 July 2000 Abstract; Figs 1-4; Col 1 Line 7 – Col 4 Line 19	1-15
X	US 2012/0085836 A1 (TIU et al) 12 April 2012 Abstract; Figs 1-9; Paras 0076-0093	1-15
X	WO 2015/010160 A1 (FLINDERS PORTS PTY LTD) 29 January 2015 Abstract; Figs 1-6; Para 0001-0070	1-15
A	US 2006/0257251 A1 (CARLSON et al) 16 November 2006 Whole document	
A	WO 2014/045179 A1 (SPAL AUTOMOTIVE S.R.L.) 27 March 2014 Whole document	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2016/050663

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Supplemental Box

Continuation of: **Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-8 are directed to a fan assembly including a plurality of fan blades, an annular shroud including a plurality of radial spokes, an air intake guard including a plurality of radial spokes, a stator including a plurality of radial spokes, and a liquid delivery arrangement including a plurality of discharge outlets. The feature of an annular shroud including a plurality of radial spokes, an air intake guard including a plurality of radial spokes, a stator including a plurality of radial spokes, and a liquid delivery arrangement including a plurality of discharge outlets is specific to this group of claims.

- Claims 9-12 are directed to a fan assembly including a plurality of blades, an annular shroud including a plurality of radial spokes, and an air intake guard including a plurality of radial spokes formed in a conical array. The feature of an annular shroud including a plurality of radial spokes, and an air intake guard including a plurality of radial spokes formed in a conical array is specific to this group of claims.

- Claim 13 is directed to a fan assembly including a plurality of fan blades, an annular shroud including a plurality of radial spokes being formed as fixed vanes, the vanes having an angle of attack greater than zero. The feature of an annular shroud including a plurality of radial spokes being formed as fixed vanes, the vanes having an angle of attack greater than zero is specific to this group of claims.

- Claim 14 is directed to a fan assembly including a plurality of fan blades, an annular shroud including a plurality of radial spokes, a stator including a plurality of radial spokes being formed as fixed vanes, the vanes having an angle of attack greater than zero. The feature of an annular shroud including a plurality of radial spokes, a stator including a plurality of radial spokes being formed as fixed vanes, the vanes having an angle of attack greater than zero is specific to this group of claims.

- Claim 15 is directed to a fan assembly including a plurality of fan blades, an annular shroud, and a liquid delivery arrangement including a plurality of discharge outlets. The feature of a liquid delivery arrangement including a plurality of discharge outlets is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is a fan assembly including a plurality of fan blades and an annular shroud.

However it is considered that this feature is generic in this particular art. Therefore in this light this common feature cannot be a special technical feature. Hence there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori* .

INTERNATIONAL SEARCH REPORT	International application No. **PCT/AU2016/050663**

Supplemental Box

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2016/050663**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
GB 1335896 A	31 October 1973	GB 1335896 A	31 Oct 1973
US 3655130 A	11 April 1972	US 3655130 A	11 Apr 1972
US 3706417 A	19 December 1972	US 3706417 A	19 Dec 1972
US 6257502 B1	10 July 2001	US 6257502 B1	10 Jul 2001
US 2013/0219933 A1	29 August 2013	US 2013219933 A1	29 Aug 2013
		WO 2013126093 A1	29 Aug 2013
US 6086053 A	11 July 2000	US 6086053 A	11 Jul 2000
US 2012/0085836 A1	12 April 2012	US 2012085836 A1	12 Apr 2012
		US 9119386 B2	01 Sep 2015
		AU 2010228116 A1	20 Oct 2011
		AU 2010228116 B2	21 Jan 2016
		NZ 595362 A	30 May 2014
		WO 2010108221 A1	30 Sep 2010
WO 2015/010160 A1	29 January 2015	WO 2015010160 A1	29 Jan 2015
		AU 2014295809 A1	18 Feb 2016
		EP 3024766 A1	01 Jun 2016
		US 2016166969 A1	16 Jun 2016
US 2006/0257251 A1	16 November 2006	US 2006257251 A1	16 Nov 2006
		US 7484925 B2	03 Feb 2009
		WO 2006137990 A2	28 Dec 2006
WO 2014/045179 A1	27 March 2014	WO 2014045179 A1	27 Mar 2014
		CN 104813568 A	29 Jul 2015
		EP 2898593 A1	29 Jul 2015
		IT BO20120499 A1	21 Mar 2014
		US 2015226224 A1	13 Aug 2015

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.