

SPECIFICATION **Electrical Fan**

The invention relates to fans having an annular flow, passage extending from an inlet opening of the fan and defined between a circumferential outer surface of a hub coaxial with and rotatable by a rotor of an electric drive motor and a coaxial annular surface, and in which blades are fixed to the hub and extend axially therealong to pass fluid along the flow passage from a suction end to a discharge end thereof.

Fans of the kind referred to above are known in which the circumferential surface of the hub diverges in the flow direction and the hub is hollow and open at its rear end to accommodate at least part of the drive motor (see German OLS 1924611). However, the apex angle of the circumferential surface of the hub at the discharge end of the flow passage is 180° and hence the fan has the characteristics of a radial fan and can only be used as such.

When in operation, radial fans often have a particularly high power demand and cause correspondingly high noise levels particularly where, due to the special characteristics thereof, the motor speed rises in a particular range of the characteristic curve. In the case of household equipment mounted in conjunction with sheet metal walls it is particularly important that a fan should have low noise levels. The same applies with respect to the ventilation of electrical equipment, for example data-processing installations, installed in standard sheet metal boxes and where strict requirements are made regarding low noise levels. Due the different types of appliances to be ventilated with the same fan and also the different operating points of a single fan, there are numerous different working points on the characteristic curve of a particular fan. In the case of these different appliances on the one hand for example a high pressure and an adequate delivery rate of the fan are required and on the other particularly in no-load operation a low noise level for the same fan. Such contradictory requirements can only be fulfilled in an unsatisfactory manner with known fans.

An object of the present invention is to so further develop a fan of the type defined hereinbefore that it combines the maximum number of advantages of both a radial and an axial fan.

According to the invention, this problem is solved in that said coaxial annular surface is the locus of the outer edges of the axially extending blades fixed to the hub, and the circumferential surface of the hub and the annular surface both continuously diverge from the hub axis in the flow direction along said flow passage with said surfaces subtending respective acute apex angles over at least substantially the entire length of the flow passage, and the cross-sectional area of the flow passage does not decrease throughout its length in the flow direction.

In the case of small fans, the motor capacity

and consequently the speed are dependent on the mode of operation. With the fans according to the present invention, this dependence is minimal over a relatively long part of the fan characteristic curve, so that numerous possible uses are covered.

Compared with known arrangements using radial fans requiring higher torques, the present invention permits, in addition to reducing the driving power (or if desired a reduction in the size of the motor) due to the approximately constant speed over the range of the characteristic, an optimum construction of the motor from the power standpoint for the particular operating speed (i.e. additional improvement of the efficiency of the drive motor without further reduction in its size).

The so-called diagonal fan (i.e. axial input with radial output) according to the present invention also reduces the noise in the characteristic range used compared with the known arrangements. Furthermore, the motor power reduction is possible as a result of the invention and can be utilised for reducing noise, because a more powerful fan motor can run more slowly and therefore more quietly in the case of the same power of blowing air.

The so-called diagonal fan according to the present invention is able to combine the specific advantages of axial fans (axial delivery direction) and radial fans (axial suction flow, radial delivery, i.e. a 90° deflection) and therefore offers further advantages in the intermediate range between the optimum range for the axial fan and that for the radial fan.

At the same voltage, the diagonal fan according to the present invention can run at higher pressure with approximately unchanged speed or can consume approximately constant power over the characteristic range used in practice. Further, the fan according to the present invention can be constructed in such a way that it runs faster at high pressure than under no-load condition.

According to the present invention therefore, there is provided a fan having an annular flow passage extending from an inlet opening of the fan and defined between a circumferential outer surface of a hub coaxial with and rotatable by a rotor of an electrical drive motor and a coaxial annular surface which is the locus of the outer edges of axially extending blades fixed to the hub wherein the circumferential surface of the hub and the annular surface both continuously diverge from the hub axis in the flow direction along the said flow passage with said surfaces subtending respective acute apex angles over at least substantially the entire length of the flow passage and the cross-sectional area of the flow passage does not decrease throughout its length in the flow direction. Preferably, the outer edges of the fan are free, i.e. the fan is non-shrouded.

Usually, the hub will be fixed to and rotatable with the rotor and the circumferential outer surface of the hub and the annular surface will be

axially symmetrical with respect to the rotor axis. As indicated above, the fan is of particular use as a diagonal fan in which it sucks in axially at its inlet end and blows out radially at its outlet end. Further, it is also preferred that the hub is hollow and open at its rear end to accommodate at least part of the drive motor therein. Moreover, it is preferred that the apex angle of the hub is greater than the apex angle of the annular surface and that the generators of the circumferential outer surface of the hub and the annular surface are substantially straight in the flow direction. Also, as mentioned previously, the invention has particular application to small fans for example in which the diameter of the discharge end of the annular surface is 30 cm or less. Similarly, the invention has particular application to fans having an axial length which is shorter than the diameter of the discharge end of the annular surface.

Advantageous flow relationships are obtained if the ratio of the flow cross-section at the suction end of the flow passage between the annular surface and the circumferential surface to the flow cross-section at the discharge end of this flow passage is in the range 10:10 to 10:15 and preferably 10:13.

Due to the shaping and profiling of the blades, a favourable influence can be exerted on the flow, for example by making the blades convex or concave, when viewed in the rotation direction. An annular wall enclosing the flow channel and which extends along the locus can aid the flow. Such an annular wall can either be stationary or rotate. If it is to rotate, it usually is fixed and rotatable with the hub. A more advantageous flow guidance at the suction end is obtained if the flow passage is externally enclosed by an annular wall extending along the locus and which along its suction end is thickened by a swelling which projects radially outwards.

The same fan according to the invention can be operated under no-load condition, i.e. with a blowing direction approximately in the form of an extension of the flow passage formed between circumferential surface and annular surface. However, at the discharge side, the flow can also be wholly or partly radially deflected. According to a corresponding embodiment of the invention, the flow passage is externally enclosed by an annular wall extending along the locus and on the discharge side projects beyond the flow passage and is widened to an obtuse apex angle which is significantly larger than that of the annular surface to face a stationary flat baffle plate, preferably perpendicular to the motor axis, to form an annual diffuser which is radially open towards the outside.

An undesired vortex effect on the baffle plate can be reduced if on the discharge side, a stationary baffle plate is provided behind the hub and which in the flow direction diverges coaxially towards the motor axis with an obtuse apex angle which is significantly larger than that of the circumferential surface.

Preferably, the drive motor is an external rotor-type motor with a two-pole stator, preferably an asynchronous motor. The stator can easily be constructed in such a way that it can at least mainly be located within the axial length of the hub and in this way the total axial space requirements for the fan are reduced.

It is advantageous to seek for the drive motor a ratio of the length (e) of the magnetic field lines within the motor to the air gap diameter (d) of 1:3 or higher, particularly in the case of a two-pole motor. A higher e/d ratio means a high efficiency. However, as this is frequently limited by axial installation restrictions, e/d can only be increased if a smaller motor capacity is possible and as provided by the present invention. A higher e/d can also be used, in order to save space in the fans according to the invention, because the motor is less powerful, i.e. can have a smaller diameter, which is an additional advantage or permits such an advantage in the case of small impeller diameters.

A fan according to the present invention using for example an asynchronous motor with a relatively high ohmic rotor resistance, when under no-load condition at a relatively low speed may be required to supply a given delivery rate, whilst running quietly and providing an adequate supply when working under load. This can be achieved by resistance-increasing alloying additives in the material (aluminium) of the cage which is situated in the short-circuit rotor of the driving motor. The pull-out torque is then at a lower speed, so that the steepness of the stable range of the speed characteristic curve is smaller. The motor is "softer", i.e. there is an improvement in the adjustability in the range of lower speeds (e.g.) down to 1400 r.p.m. in the case of two-pole motors). This additional adjustability may prove very advantageous in certain cases.

The following is a description, by way of example only and with reference to the accompanying drawing of presently preferred embodiments of the invention.

In the drawings:—

Fig. 1 is a cross-section of an impeller of a fan in accordance with one embodiment of the invention;

Fig. 2 is a graph showing flow characteristic curves of certain fans;

Fig. 3 is a partial section through a small fan according to said embodiment;

Fig. 4 is a graph showing the supply characteristic curves for the fan of Fig. 3;

Fig. 5 is a partial section through a left-hand part of a small fan according to another embodiment of the invention in part section;

Fig. 6 is a view in the direction of arrow VI in Fig. 5;

Fig. 7 is a further graph showing supply characteristic curves for certain fans;

Fig. 8 is a cross-section of a right-hand half of a small fan according to a further embodiment of the invention;

Fig. 9 is a view corresponding to that of Fig. 8

of a modification of the embodiment of Fig. 8.

In Fig. 1, 1 is an impeller, whose hub 2 is widened at an apex angle 3 of 60° in the flow direction (indicated by arrows 4). The hub 2 is axially symmetrical to the rotational axis 5 and its

end remote from the flow and shown to the right in Fig. 1 is hollowed out and to save space is inverted over an electrical drive motor (not shown). Seven blades of which only two 8, 9 are

shown are distributed over the periphery of circumferential surface 6 and their radially outer edges 10, 11 extend along a locus 12 which is coaxial to axis 5, whilst leaving the necessary tolerances. This locus 12 is the radially inner surface of a stationary annular wall 13 coaxial to axis 5 and widens in the flow direction with an apex angle 14 of 55° . A swelling 15 extends along the suction end on annular wall 13 and projects outwards, i.e. with respect to the dotted line 25 and therefore aids flow. The flow channel 22 between circumferential surface 6 and annular surface 12 has the same flow cross-section over its entire length. The flow-facing edges 16 of blades 8, 9 do not extend completely up to the suction end of the annular wall. Edges 16 and 17 of the blades extend radially. In certain circumstances, it is advantageous to incline the edges as shown by dotted lines 18, 19, 20, 21. The annular flow cross-section 23 at the suction end is the same as the annular flow cross-section 24 at the discharge end.

The pressure rise Δp is plotted against the volume flow V in Fig. 2. Curve R is a typical curve for a radial fan and curve A a typical curve for an axial fan, whilst curve D is the characteristic curve of a fan according to the invention. The areas in which the fan can be operated with high efficiency and low noise are indicated by continuous lines and the remaining areas by dotted lines.

Fig. 2 shows that a fan according to the invention can have a broad application range with respect to pressure increase and volume flow, whereas radial fans are limited to a narrow range relative to volume flow and axial fans to a narrow range relative to pressure increase.

In Fig. 3, 30 is a stationary baffle plate to which is fixed by means of bolts 31 uniformly distributed over the periphery an annular wall 33 which is axially symmetrical about axis 32 and which in the flow direction (indicated by arrow 34) widens to an acute apex angle and whose inner surface forms the locus 36. 51 is a swelling corresponding to swelling 15. Impeller 37, whose blades are 38 and 52, is mounted coaxial to axis 32. For reasons of clarity the blades facing the viewer are not shown in Fig. 3. Hob 42 is the rotor of an electrical external rotor-type motor 39, whose stator is 40. Part 41 of the rotor projects out of hub 42. A deflector 45 curved towards axis 32 extends between circumferential surface 43 and baffle plate 30.

A diffuser wall 46 fixed to bolts 31 extends parallel to baffle plate 30. Flow channel 35 is annular and is located between circumferential

surface 43 and annular surface 36 and also contains the blades 38. It is followed by an annular, outwardly directed diffuser 53, bounded on one side by diffuser wall 46 and on the other by deflector 45 and baffle plate 30 and then discharges to the exterior. The annular intake cross-section along dotted line 54 is somewhat smaller than the annular outlet cross-section of the flow channel along dotted line 55. The size ratio of inlet cross-section to outlet cross-section is advantageously 10:13. The bolts 31 are located in the flow and may disturb it in certain cases. They are rendered superfluous if diffuser wall 46 and annular wall 43 are fixed in the indicated position in some other way with respect to baffle plate 30, e.g. by more remotely positioned fixing members. The annular cross-section along line 56 is the same size as that along line 55.

The deflector 45 adopts closely to the flow and forms a gentle, constant and substantially bend-free transition from circumferential surface 43 to the surface of the deflector plate 30. The dotted line 48 indicates a modified front edge of the blades.

In Fig. 4, the characteristic curve O_R corresponds to the embodiment of Fig. 1 operated under no-load condition, i.e. without diffuser. Curve $R_{0.05}$ corresponds to the embodiment of Fig. 3 with diffuser, whilst curve R_s corresponds to the embodiment to be described below with reference to Figs. 5 and 6.

In the embodiment of Figs. 5 and 6, motor 60 is an internal rotor-type motor fixed to the baffle plate 61 by means of a flange 62 and which passes through the said plate by means of an opening 63. Hub 64 is fixed to the shaft end 59 of motor 60 and is partly inverted over the motor. The flow channel is defined by circumferential surface 65 and locus 66 of annular wall 67, which are arranged coaxially to motor axis 68. Blades 69, which are fixed to the hub along the circumferential surface, are positioned in flow channel 79. The hub widens in the flow direction with an apex angle of 85° and the torus 66 with an apex angle of 83° . Behind the hub 64 is arranged a baffle ring 70 extending in the flow direction coaxial to axis 68 and which widens in funnel-shaped manner with its baffle face 71 and at an apex angle 72 which is significantly larger than that of the circumferential surface 65. Baffle face 71 passes in substantially bend-free manner from circumferential surface 65 to the surface of baffle plate 61.

The flow channel 79 issues into an annular diffuser which is on the one hand bounded by a channel wall 73 and on the other by the baffle face 71 and which is given the reference numeral 74. Diffuser 74 issues into a channel 75 which surrounds the whole fan and is widened in the rotation direction (arrow 76) and issues into an outlet 78 directed tangentially (arrow 77) from which the delivered air is blown (arrow 77).

According to circumstances, the blades in the fans according to the invention are either profiled or unprofiled, convex or concave or even flat. If

when viewed in the rotation direction the blades are convex, then a particularly high capacity is obtained, but the noise is somewhat higher and the efficiency somewhat lower, as indicated by characteristic curve K in Fig. 7. However, if in the rotation direction the blades are concave, i.e. hollow, a higher efficiency and lower noise level are obtained, but the partial loss of power is somewhat lower, as indicated by curve G in Fig. 7.

10 Curve K was measured at a 25 Watt air output, an efficiency of 57% and a noise index of 64 dB(A) at a speed of 2240 r.p.m.. Curve G was measured with the same fan as curve K, the only change being that the convex blades in one case were

15 replaced by identical concave blades in the other. The efficiency was then 69%, with a noise level of 62 dB at 2610 r.p.m.. The test fan with which these measurements were performed was driven by a two-pole external rotor-type asynchronous

20 motor and it was found that the indicated speeds remained unchanged over the entire characteristic curve shown in Fig. 7.

According to the invention, it is advantageous in the case of an external rotor-type motor to

25 combine the rotor with the impeller hub into a single structural unit, e.g. as shown in Figs. 8 and 9.

According to Fig. 8, the rotor of an external rotor-type motor is designated by 90. The

30 laminated plates of the rotor are designated by 91. A collar 92 is fitted level with the laminated plates and widens the outer contour of the rotor towards that of hub 93 and forms the circumferential surface 94 to which are fixed the

35 blades 95. Annular wall 97, which in this embodiment also rotates, is fixed to the outer edges of the blades. Flow channel 98 extends between the locus 99 formed by the inside of annular wall 97 and circumferential surface 94.

40 Circumferential surface 94 is followed by the stationary deflector 96 which radially deflects the flow. It should be noted that the blades only extend up to the end of collar 92, so that the front end of the hub formed by the external rotor is free.

45 In Fig. 9, the external rotor 101 has the form desired for hub 102 and forms circumferential surface 103 to which are fixed blades 104. On their discharge end the blades project beyond hub 102 and extend into the area of deflector 105, which in this embodiment also extend

50 circumferential surface 103.

Blades 95 or 104 can be fixed to the hub by casting, welding or keying. They can also be fixed to a special mounting ring which is in turn fixed to the hub, e.g. fitted or keyed onto the hub.

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It will be appreciated that the invention is not restricted to the particular details described above but that numerous modifications and variations can be made without departing from the invention as defined in the following Claims.

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Claims

1. A fan having an annular flow passage extending from an inlet opening of the fan and defined between a circumferential outer surface

65 of a hub coaxial with and rotatable by a rotor of an electrical drive motor and a coaxial annular surface which is the locus of the outer edges of axially extending blades fixed to the hub wherein the circumferential surface of the hub and the

70 annular surface both continuously diverge from the hub axis in the flow direction along the said flow passage with said surfaces subtending respective acute apex angles for at least substantially the entire length of the flow passage

75 and the cross-sectional area of the flow passage does not decrease throughout its length in the flow direction.

2. A fan as claimed in Claim 1 wherein the outer edges of the fan are free.

80 3. A fan as claimed in Claim 1 or Claim 2 wherein the hub is fixed to and rotatable with the rotor.

4. A fan as claimed in any one of the preceding claims wherein the circumferential outer surface

85 of the hub and the annular surface are axially symmetrical with respect to the rotor axis.

5. A fan as claimed in any one of the preceding claims wherein the fan sucks in axially at its inlet and blows out radially at its outlet.

90 6. A fan as claimed in any one of the preceding Claims wherein the hub is hollow and open at its rear end and accommodates at least part of the drive motor therein.

7. A fan as claimed in any one of the preceding

95 claims wherein the apex angle of the hub is greater than the apex angle of the annular surface.

8. A fan as claimed in any one of the preceding claims wherein the generators of the

100 circumferential surface of the hub and the annular surface are substantially straight in the flow direction.

9. A fan as claimed in any one of the preceding claims wherein the fan has an axial length which

105 is shorter than the diameter of the discharge end of the annular surface.

10. A fan as claimed in Claim 9 wherein the diameter of the discharge end of the annular surface is 30 cm or less.

110 11. A fan as claimed in any one of the preceding claims wherein the ratio of the flow passage cross-section at its suction end to the flow passage cross-section at its discharge end is in the range 10:10 to 10:15.

115 12. A fan as claimed in Claim 11 wherein said ratio is 10:13.

120 13. A fan as claimed in any one of the preceding claims wherein the flow passage is enclosed by an annular wall extending along the said locus.

14. A fan as claimed in Claim 13 wherein the annular wall is thickened along its suction end by a swelling which projects radially outwards.

15. A fan as claimed in Claim 13 or Claim 14 wherein said wall is fixed relative to a housing of the fan.

16. A fan as claimed in Claim 12 or Claim 13 wherein the annular wall is fixed to and rotatable with the hub.



when viewed in the rotation direction the blades are convex, then a particularly high capacity is obtained, but the noise is somewhat higher and the efficiency somewhat lower, as indicated by characteristic curve K in Fig. 7. However, if in the rotation direction the blades are concave, i.e. hollow, a higher efficiency and lower noise level are obtained, but the partial loss of power is somewhat lower, as indicated by curve G in Fig. 7.

- 10 Curve K was measured at a 25 Watt air output, an efficiency of 57% and a noise index of 64 dB(A) at a speed of 2240 r.p.m.. Curve G was measured with the same fan as curve K, the only change being that the convex blades in one case were replaced by identical concave blades in the other.
- 15 The efficiency was then 69%, with a noise level of 62 dB at 2610 r.p.m.. The test fan with which these measurements were performed was driven by a two-pole external rotor-type asynchronous motor and it was found that the indicated speeds remained unchanged over the entire characteristic curve shown in Fig. 7.

- 20 According to the invention, it is advantageous in the case of an external rotor-type motor to combine the rotor with the impeller hub into a single structural unit, e.g. as shown in Figs. 8 and 9.

- 30 According to Fig. 8, the rotor of an external rotor-type motor is designated by 90. The laminated plates of the rotor are designated by 91. A collar 92 is fitted level with the laminated plates and widens the outer contour of the rotor towards that of hub 93 and forms the circumferential surface 94 to which are fixed the blades 95. Annular wall 97, which in this embodiment also rotates, is fixed to the outer edges of the blades. Flow channel 98 extends between the locus 99 formed by the inside of annular wall 97 and circumferential surface 94.

- 40 Circumferential surface 94 is followed by the stationary deflector 96 which radially deflects the flow. It should be noted that the blades only extend up to the end of collar 92, so that the front end of the hub formed by the external rotor is free.

- 45 In Fig. 9, the external rotor 101 has the form desired for hub 102 and forms circumferential surface 103 to which are fixed blades 104. On their discharge end the blades project beyond hub 102 and extend into the area of deflector 105, which in this embodiment also extend circumferential surface 103.

- 50 Blades 95 or 104 can be fixed to the hub by casting, welding or keying. They can also be fixed to a special mounting ring which is in turn fixed to the hub, e.g. fitted or keyed onto the hub.

- 55 It will be appreciated that the invention is not restricted to the particular details described above but that numerous modifications and variations can be made without departing from the invention as defined in the following Claims.

Claims

1. A fan having an annular flow passage extending from an inlet opening of the fan and defined between a circumferential outer surface

- 65 of a hub coaxial with and rotatable by a rotor of an electrical drive motor and a coaxial annular surface which is the locus of the outer edges of axially extending blades fixed to the hub wherein the circumferential surface of the hub and the annular surface both continuously diverge from the hub axis in the flow direction along the said flow passage with said surfaces subtending respective acute apex angles for at least substantially the entire length of the flow passage and the cross-sectional area of the flow passage does not decrease throughout its length in the flow direction.

2. A fan as claimed in Claim 1 wherein the outer edges of the fan are free.

- 80 3. A fan as claimed in Claim 1 or Claim 2 wherein the hub is fixed to and rotatable with the rotor.

4. A fan as claimed in any one of the preceding claims wherein the circumferential outer surface of the hub and the annular surface are axially symmetrical with respect to the rotor axis.

5. A fan as claimed in any one of the preceding claims wherein the fan sucks in axially at its inlet and blows out radially at its outlet.

- 90 6. A fan as claimed in any one of the preceding Claims wherein the hub is hollow and open at its rear end and accommodates at least part of the drive motor therein.

7. A fan as claimed in any one of the preceding claims wherein the apex angle of the hub is greater than the apex angle of the annular surface.

8. A fan as claimed in any one of the preceding claims wherein the generators of the circumferential surface of the hub and the annular surface are substantially straight in the flow direction.

9. A fan as claimed in any one of the preceding claims wherein the fan has an axial length which is shorter than the diameter of the discharge end of the annular surface.

10. A fan as claimed in Claim 9 wherein the diameter of the discharge end of the annular surface is 30 cm or less.

- 110 11. A fan as claimed in any one of the preceding claims wherein the ratio of the flow passage cross-section at its suction end to the flow passage cross-section at its discharge end is in the range 10:10 to 10:15.

- 115 12. A fan as claimed in Claim 11 wherein said ratio is 10:13.

13. A fan as claimed in any one of the preceding claims wherein the flow passage is enclosed by an annular wall extending along the said locus.

- 120 14. A fan as claimed in Claim 13 wherein the annular wall is thickened along its suction end by a swelling which projects radially outwards.

15. A fan as claimed in Claim 13 or Claim 14 wherein said wall is fixed relative to a housing of the fan.

16. A fan as claimed in Claim 12 or Claim 13 wherein the annular wall is fixed to and rotatable with the hub.

17. A fan as claimed in Claim 15 or Claim 16 wherein the annular wall extends beyond the discharge end of the flow channel and widens downstream of said end to an obtuse apex angle. 18. A fan as claimed in Claim 17 wherein the baffle plate extends perpendicularly to the rotor axis.

10 19. A fan as claimed in Claim 5 or any one of Claims 6 to 8 including the feature of Claim 5, wherein a stationary baffle plate is provided coaxially down-stream of the hub and diverges in the flow direction to an obtuse apex angle.

15 20. A fan as claimed in Claim 17 or Claim 18 wherein an annular, curved deflector coaxial to the motor axis is provided which bridges the gap between the circumferential surface and the baffle plate in a continuous smooth manner.

20 21. A fan as claimed in Claim 5 or any one of Claims 6 to 20 when including the feature of Claim 5, wherein a discharge channel is provided which widens in the rotation direction of the hub and surrounds the flow passage outlet to connect

25 said flow channel with a tangentially directed outlet port.

22. A fan as claimed in any one of the preceding claims, wherein the drive motor is an external rotor-type motor with a cup-shaped rotor, whose closed rotor end forms the suction end of the hub.

23. A fan as claimed in any one of Claims 1 to 21 wherein the drive motor is an external rotor-type, whose stator has two poles and is at least substantially located within the axial length of the hub.

24. A fan as claimed in any one of the preceding claims wherein the apex angle of the hub is about 60° and the apex angle of the annular surface is about 55° .

25. A fan substantially as described with reference to and as shown in Figures 1 and 3.

26. A fan substantially as described with reference to and as shown in Figures 5 and 6.

27. A fan substantially as described with reference to and as shown in Figure 8.

28. A fan substantially as described with reference to and as shown in Figure 9.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1982. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

